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ABSTRACT

The Career Area Rotation Model (CAROM) was developed as a result of the need for a computer based model describing the rotation of airmen within a specific career area (occupational specialty) through various categories of tour duty, accommodating all policies and interactions which are relevant for evaluation purposes. CAROM is an entity simulation (gaming) model providing long term projections, up to 30 years. This user's manual provides user-oriented documentation in sufficient detail to give the prospective user a complete group of the concepts and logic underlying the model. The presentation includes: (a) a comprehensive overview of the system; (b) a description of the system's modules and the interrelationships of their inputs and outputs; (c) detailed instructions on input card formats, with appropriate discussion as to the relationship between input parameters and applications of the model; and (d) a description and explanation of reports generated by the model. (Author/DS)

AFHRL-TR-73-49

AIR FORCE HUMAN RESOURCES LABORATORY

CAREER AREA ROTATION MODEL

USER'S MANUAL

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The Career Area Rotation Model was designed as a managerial aid for investigating and evaluating the various and diverse policy interactions which impact on the deployability posture of the Air Force. This user's manual provides user-oriented documentation in sufficient detail to give the prospective user a complete grasp of the concepts and logic underlying the model. The presentation includes: (a) a comprehensive overview of the system; (b) a description of the system modules and the interrelationships of their inputs and outputs; (c) detailed instructions on input card formats, with appropriate discussion as to the relationship between input parameters and applications of the model; and (d) a description and explanation of reports generated by the model.

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PREFACE

This work was completed under Project 7906, Fundamental Research on Methods of Simulating the Air Force Personnel System; Work Unit 79060102, Development of Computer-Based Methods of Simulating the Redistribution of Air Force Enlisted Personnel Within an Occupational Area.

The development and computer programming of the Career Area Rotation Model was carried out under the provisions of Contract Number F41609-71-C-0034, by Decisions Systems Associates, Incorporated. Mr. Rodney Morton was the Principal Investigator. Richard B. Williams acted as Contract Monitor for the Air Force Human Resources Laboratory.

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I. INTRODUCTION

Background

Manpower management activities within the Air Force have become increasingly reliant upon computerized methodologies to achieve maximum utilization of available resources within existing budgetary and policy-related constraints. For example, to assist with the typical manpower planning activities such as requirements planning, the development of unit manning levels, promotion plans and recruitment plans, etc., models employing mathematical methodologies such as linear programming or network flow theory have been developed and successfully applied. And to assist with day-to-day operational personnel decisions such as the assignment of recruits to entry-level training and the reassignment of enlisted personnel, computer-based assignment systems have been developed and implemented in all four services.

In addition to these types of models, a particular requirement exists in the services for a capability to assess the complex interactions of personnel policies and, specifically, to pretest the impact of proposed policy alternatives in the simulated environment. Such a capability is necessary because the feasibility of testing and evaluating policy alternatives in the "field" is doubtful, to say the least, whereas the potential costs associated with such field tests would be enormous, both in terms of dollar costs and intangible costs. Further, a policy assessment capability is most desirable because personnel policies have a strong impact on the possible utilization of available personnel -- an impact which often cannot be assessed a priori through expert judgment. Alternative cut-off scores on the selection relevant aptitude area tests for certain training opportunities are difficult to assess a priori. Similarly, policies governing the assignment eligibility of airmen to billets or authorized assignment categories (i.e., through specification of acceptable tour sequences, grade/skill level substitutions, etc.) strongly determine the Air Force's capability of manning its units as planned. Again, the impact of alternative

substitution policies or tour sequence policies is difficult to assess a priori.

While the need for a policy assessment capability is thus well-established, the tools required to fill that need adequately have been lacking in the past. Recent advances in computer-assisted simulation techniques, however, have provided the practical feasibility of developing simulation models capable of assisting with the assessment of policy alternatives. Simulation models developed for this type of use are commonly referred to as gaming models. Judicious use of gaming models can thus contribute to significant improvements in the management and utilization of the airman force. The potential contribution of a gaming model becomes most significant, of course, whenever the problem area involves such a large number of interacting policies that expert judgment alone is incapable of providing any reasonable evaluation of the impacts of possible policy alternatives. A gaming model becomes critical when the personnel system undergoes significant changes from traditional practices of the past such as the current transition toward an All Volunteer Force.

A prime example of a complex problem area in need of a gaming model is the rotation and reassignment of airmen or, in more general terms, the effect of deployment, rotation and assignment policies upon the deployability posture of the airman force. The reason for this need is the large number of complex interactions between the policies associated with airman rotation; e.g., the priority scheme for tour categories, tour durations, tour sequences, limits on the number of tours in a specific tour category, restrictions on certain tour duties due to ETS (expiration of term of service) or other parameters, grade and skill level substitutions, promotion policies, etc. To help personnel managers make educated assessments of the complex interactions of policy alternatives as they affect the deployability posture of the airman force, the Personnel Research Division (AFHRL) has embarked on the development of a computer-based model describing the rotation of airmen within a specific career area (occupational specialty) through various categories of tour duty, accommodating

all policies and interactions which are relevant for evaluation purposes. The design specifications for this model, the Career Area Rotation Model (CAROM), were developed by the Simulation Research Section of the Computer and Management Sciences Branch, Personnel Research Division. The contract for development, computer programming and testing of the model was awarded to Decision Systems Associates, Inc., of Rockville, Maryland. During the model design phase, the original contract was amended by the Personnel Research Division to extend the scope of the model and to increase significantly the model capabilities. The model has been developed in accordance with those amended design specifications and, after extensive testing, has become available for operational use in the Air Force's manpower and policy planning activities.

CAROM is an entity simulation model[1] providing long-term (up to thirty years) projections of the consequences of a given set of rotation, deployment and assignment policies under a wide variety of assumptions regarding manning requirements, attrition rates, early-out policies, promotion policies, output from the entry-level training line, etc. Due to its level of detail and the optimal assignment capability imbedded within the model, CAROM is perfectly suited for gaming applications to assess the relative effects of proposed changes in policies and parameters. The model is flexible, easy to use and cost-effective in terms of computer run costs. Applications of CAROM are numerous, and its potential for contributing to improved management and utilization of the airman force is significant.

Purpose and Scope of Manual

This User's Manual provides detailed, user-oriented documentation for the Career Area Rotation Model. The documentation is sufficiently detailed so the prospective user can

[1] One important classification of simulation models in general refers to the level of discrimination employed in the model. Entity models process each entity (i.e., individual airmen) separately, applying a given logic to each entity. Aggregate models, on the other hand, deal with aggregates (i.e., categories of airmen with certain attributes in common) and do not discriminate between members of the same aggregate. Needless to say, entity models are, in general, more precise than aggregate models, but require more computing time and input time.

understand the model's concepts and logic and apply it to his problems. The manual includes: (a) an overview of the entire system; (b) a detailed description of the individual, functional modules composing the system and the interrelationships of the inputs to and outputs from each module; (c) detailed instructions on input card formats; (d) a description and explanation of the reports generated by the model; and (e) instructions on how to run the model.

Organization of Manual

This manual has been prepared in accordance with U.S. Air Force regulations.[2] Thus the format and layout of the manual should be familiar to the intended readership, facilitating access to and understanding of the material.

Chapter II provides an overview of the Career Area Rotation Model. It includes discussion of the model's purpose, modes of operation and design objectives. Further, the chapter contains a general description of the model's logic and the specific functions performed within the model.

Chapter III provides a detailed description of each individual module including its input, output and relationships to other modules. The operations performed by each module are summarized.

Chapter IV is of major interest to the model user. This chapter contains detailed user instructions and is divided into two main sections, input and output. In addition to control card and data file formats, content descriptions and sequencing instructions, this chapter explains the purpose and use of each data item as well as the relationship between each input and output item. The reports generated by the model are discussed in detail.

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[2] See: AFSCM/AFLCM 310-1(C1), "Users Manual (Computer Program)," Identification Number H-110-1, 15 July 1969 (DD Form 1664).

Chapter V is of major interest to the system operator. It provides detailed instructions on run submissions and the SCOPE operating system control cards required to execute the model on the CDC 6600 computer system. In addition, this chapter explains the system diagnostics which may be generated as a result of input errors. One Appendix is included for a technical description of the assignment solution approach employed in CAROM.

II. OVERVIEW OF MODEL CAPABILITIES

This chapter provides a general overview of the Career Area Rotation Model as an introduction to the more detailed, technical descriptions contained in Chapter III. The is divided into four sections which discuss:

- the purposes of the model and model applications
- the design objectives or general philosophy which guided development of the model
- the scope of the model including a brief overview of its capabilities
- the general functions performed in the model.

A. MODEL PURPOSE AND USE

The Career Area Rotation Model (CAROM) is an analytical tool for evaluating the short- and long-range consequences of alternative personnel policy configurations on the airman force and on the manning requirements of the U.S. Air Force. The model simulates a wide variety of personnel activities including accession, promotion, retention, attrition and tour rotation. A wide range of policies governing these activities may be assessed through CAROM.

The model is primarily designed for policy gaming purposes, i.e., to appraise the relative effects of policy changes on the personnel inventory and force structure. CAROM is designed to aid manpower managers in evaluating the magnitude of changes in deployment-related criteria that might occur under specific personnel policy changes or anticipated changes in attrition rates, accessions and/or authorized strengths. Two aspects of simulation capability are regarded as particularly important:

(1) The ability of the model to estimate the point at which major manpower goals (such as the attainment of authorized strengths or inventory grade or skill level distributions) become infeasible as a result of new personnel policies.

(2) The ability of the model to isolate the effects of changes to policies in one personnel area (such as promotion, accession or tour rotation) while holding constant policies in other areas.

It is important to recognize that CAROM is a planning or gaming tool rather than an operational tool. As such CAROM is designed to predict the aggregate effects of policy changes, but is not designed to predict the future status of individual airmen. Although CAROM is an entity model which simulates all major personnel activities at a realistic level, the model does not utilize personnel or structure data at the level of detail required for operational purposes. The prediction of individual career progressions or future assignments is, therefore, beyond the scope of the model.

As a gaming tool, CAROM may be used for investigating and assessing a wide variety of alternative rotation, deployment, assignment, promotion and retention policies as well as the interactions of policy changes. Examples of potential applications include the following:

- Assessment of policy-resultant nondeployability, i.e., the inability of meeting given manning requirements due to policy constraints rather than a shortage of airmen. The model accommodates all of the following deployment related factors:
  - Tour duration: CAROM divides all possible tour duties into four tour categories, Special, Remote, Accompanied Overseas and CONUS. The given tour length in each tour category (a model parameter) affects the number of airmen to

be reassigned or replaced and, therefore, the deployability posture of the force.

— Limits on number of tours: Deployment policies may impose specific limits on the number of non-CONUS tours which an airman may accrue in each tour category during his career. Such limits affect the number of airmen eligible for assignment to any particular tour category.

— Permissible tour sequences: Deployment policies may also establish permissible and impermissible tour sequences in terms of past, current and next tour category. The more restrictive these policies are, the less deployable the airman force will be.

— Minimum time since last tour: Deployment policies may also specify a minimum time since last tour for each tour category as a prerequisite for assignment eligibility to a subsequent tour in the same category. To the extent that such minimum times involve a lengthy period, one decreases the flexibility of assigning airmen where needed and reduces the number of deployable airmen.

— Minimum/Maximum time in CONUS: Deployment policies may also specify a minimum time in CONUS in order to be eligible for a non-CONUS tour; this minimum time is, typically, dependent upon the (next) tour category. Additionally, for those airmen not in stabilized positions (see below), a maximum CONUS tour length determines when they must be reassigned in CONUS. These minimum and maximum CONUS times affect the number of deployables.

— Stabilized CONUS positions: A proportion of CONUS billets may be referred to as stabilized positions in the sense that they require a specific tour length. This is simulated in CAROM by assigning a fixed tour length to a proportion of the airmen (re)assigned to CONUS whereas the remainder is subject to the minimum time in CONUS guarantee (see above) and a given maximum CONUS tour length. Airmen reassigned within CONUS (for "non-fixed" assignees upon reaching maximum CONUS tour length if not previously reassigned to a non-CONUS tour, and for "fixed" assignees upon completing their fixed CONUS tour while not reassigned to a non-CONUS tour) are again subject to the same fixed/non-fixed tour reassignment process as returnees. The number and duration of these "stabilized" positions in CONUS affect the deployability posture of the force.

— Initial duty tour for training graduates: All accessions to the model are assumed to be training graduates (primarily at the E1/E2 level from entry-level training but also at higher grades through cross-training from other career areas if the user so specifies).

— ETS restrictions on deployment: CAROM accommodates two types of Expiration of Term of Service (ETS) restrictions, both of which affect deployability. The first type of restriction is expressed in terms of the maximum time to ETS to be ineligible for transfer. Airmen completing their current tour with less obligated service time than the maximum specified will have their tour extended to ETS if (and only if) they are projected not to be retained at ETS (those who are projected to reenlist are, however, available for reassignment and do not have their tour extended). The second type of restriction is expressed in

terms of the minimum time to ETS to be eligible for assignment to a non-CONUS tour. First-term airmen in CONUS who are available for reassignment but with less time to ETS than the specified minimum must remain in CONUS if they do not reenlist. Note that this latter restriction applies only to first-term airmen. Both ETS restrictions affect the number of deployable airmen.

- Grade and/or Skill level substitutions: By design, CAROM accommodates only one career area in a given run or, viewed differently, CAROM does not distinguish different skills within the population input to the model. The sole distinction, in addition to the individual deployment-related characteristics, is by grade and skill level. Within the population, CAROM accommodates grade and/or skill level substitution policies to compensate for imbalances between available deployables and billet vacancies so as to achieve the maximum possible fill of vacant billets. As a result, grade and skill level substitution policies affect the deployability posture of the force, and the more flexible these policies, the better the Air Force's capability of manning its billets.
- Promotion policies: The number of airmen deployable in a given grade is dependent on promotion policies, and this fact is particularly relevant when grade or skill level substitution policies are very limited. CAROM simulates both grade and skill level promotions in accordance with current practices. The number of promotions by grade is dependent on which of two promotion quota systems is specified by the user. If the equal selection opportunity system is specified, then the number of promotions is dependent on a user-

specified proportion of eligibles to be promoted to each grade. If the vacancy promotion quota system is utilized, the number of promotions is dependent on the difference between the authorized and on-board strength in that grade, possible overages or shortages in the higher grades, and the number of airmen eligible for promotion to that grade. Promotion eligibility is governed by four factors: minimum time in grade, minimum time in service, maximum time in service (up-or-out policy) and minimum skill level. Simulation of individual promotions is performed in accordance with the weighted airman promotion system (WAPS). For that purpose, CAROM updates periodically the factors composing the WAPS score in accordance with given statistical distributions. Promotion of skill level is a simpler process, with eligibility governed by minimum time in skill level and appropriate grade and with date of promotion determined randomly from a given distribution of fixed times past the minimum time in skill. Thus, through specification of the promotion prerequisites, the promotion flow may be regulated to control the number available in a given grade and/or skill level.

- Distribution policies: In the event that not all vacancies can be filled, either due to a shortage of airmen eligible for reassignment or due to a grade/skill level imbalance between

those available versus needed, distribution policies determine the share which each tour category receives as well as the relative "fill" within each tour category by grade and/or skill level. CAROM accommodates any rational set of distribution policies, expressed in terms of absolute priorities and/or relative sharing coefficients.

Many of the above factors may be specified separately and independently for first-term and career airmen. Moreover, most of these factors are dynamic in the sense that different values may be specified for different periods of the simulation which extends to a maximum of 360 months. CAROM may be used for assessing any combination of the above factors in terms of the impact on the deployability posture of the airman force. Specifically, the CAROM reports provide information on the basic evaluation criterion, the supportability (i.e., per cent fill) of given authorized strengths by tour category, as well as the extent of grade or skill level substitution required to achieve that fill.

- Assessment of promotion policies: Through specification of alternative promotion policies (particularly, the promotion prerequisites for each grade), it is possible to evaluate the consequences in terms of promotion flow.
- Sensitivity analysis: For effective management of the airman force, it is essential that managers have a good "feel" for the sensitivity of the personnel system to the various factors, both independently and in

combination. CAROM provides an invaluable tool for the development of such insights. In addition to the deployment-related factors discussed above, the model accommodates a large number of other factors which govern the maturation of the force; e.g., initial inventory, accessions, authorized strengths, involuntary losses (exceptional attritions as well as forced attritions), voluntary losses (ETS losses as well as early-outs), etc.

Like many gaming models, CAROM may be used for other purposes than strictly policy assessment. To the extent that the model user is able to estimate the required parameters (incidentally, a requirement for any manpower planning activity, using a model or not), CAROM may be used in support of the development of various manpower plans. One word of caution should be noted in using CAROM as a planning tool: Due to the optimal methodologies employed by the model in the reassignment of airmen, CAROM may produce an optimistic estimate of actual manning capabilities. However, using realistic estimates of all loss rates, retention rates and other parameters, the model user may regulate the level of capability over-estimation by CAROM through specification of a special adjustment factor which controls the proportion of airmen at each non-CONUS tour category which are ineligible for reassignment for non-obvious reasons (i.e., airmen who are eligible for reassignment under the policies and procedures simulated by the model but who will not be reassigned at that point for other reasons such as human factors, inefficiencies in the field, etc.) Through careful calibration of the model, it is thus possible to use CAROM as a realistic planning tool. Examples of this type of model application include the following:

- Estimation of maximum manning capabilities under current policies.
- Rapid evaluation of short- and long-range consequences of specifically proposed accession plans and promotion, deployment and assignment policies.

- Detection or anticipation of manning problems caused by uncontrollable factors (e.g., projected changes in retention rates or accession availabilities) and the evaluation of alternative solutions to such problems.
- Estimation of the entry-level training requirement. If the trained accessions initially specified by the user result in overages or shortages in the model, the overages or unfilled billets, respectively, may be used as guidance in determining what the output from the entry-level training line ought to be. In turn, these figures may be fed back to the Training Line Simulator[3] to determine what the raw recruit intake schedule ought to be.
- Development of early-out and forced attrition plans.
- Development of promotion plans.
- Development of unit manning levels or strength authorizations.

This preview of the model's capabilities concludes this section on model purpose and use. Subsequent sections of this Chapter provide a more detailed description of the model's capabilities and functions.

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[3] The Training Line Simulator (TLS) is an entity simulation model designed to project the consequences of alternative training policies and plans. The model simulates the flow of airmen from entry into the Air Force into basic training through graduation from entry-level technical training. The model accepts a user-specified accession flow consisting of recruit data records containing all training relevant attributes. After graduation from basic training, the model makes an optimal assignment of each week's graduates to technical training courses available for that week. Training parameters accommodated by the model include attrition, setback and washahead rates; class schedules, quotas and class sizes for each course; and mandatory and desirable course entrance prerequisites. For a given accession flow and set of training parameters, the model determines the fill of training quotas, the waiting lines, the numbers of graduates, etc., by course for each week of the five-year projection period.

B. MODEL DESIGN OBJECTIVES

The CAROM modeling effort was guided by the following basic design objectives:

1. Optimal Assignment Capability

Capability for the realistic simulation of the rotation of airmen through various tour categories is a major CAROM goal. To achieve this capability, the CAROM allocator algorithms must be designed to incorporate objectives identical to current Air Force assignment objectives. A maximum utilization of available personnel, subject to user-specified parameters governing assignment eligibility, must be obtained. Also, a variety of rotation policies, such as grade and skill substitution, must be maximally accommodated within the optimum manning levels.

2. Level of Simulation Detail

A reasonable balance must be achieved between detail of simulation and the cost of running the model. By design specification, the model matures and rotates airmen in a single occupational specialty (career area) through four tour categories in monthly time increments. Within these specifications, the attrition, promotion and rotation aspects of the model have been designed to achieve a combination of high model operating speed, an appropriate level of simulation detail, and a maximum degree of user control over simulation activities.

3. Efficiency

Model execution costs must be a major design consideration in any large scale modeling effort, particularly in the case of a gaming type model. The large volume of personnel records associated with long-range projections and the complex processes performed by CAROM caused minimization of model running time to be a critical model design objective. This strongly influenced both the computational and structural aspects of the model.

This concern with execution efficiency has resulted in a very reasonable run time of CAROM, considering the numerous complex operations involved in the simulation. The run time is primarily dependent upon the number of records to be processed (or, more precisely, the number of airmen in the system at the same time) and, of course, the length of the simulation. A good criterion of the efficiency of the model is the number of seconds required to perform one complete pass for one simulation period (month). Test runs conducted to date on the Control Data Corporation 6600 computer system show the following results:

Number of Airmen	Simulation Length	System seconds per pass
100	60 periods	3 seconds
10,000	60 periods	40 seconds

These results indicate that due to a certain amount of overhead time, the time per pass increases less than proportionately with the number of airmen in the system. Further, there is evidence that the time per pass decreases with increasing length of simulation.

One may tentatively estimate that for 120,000 airmen not more than 400 system seconds would be required per pass. These timings include all input and output operations (but exclude off-line printing).

4. Flexibility and User Convenience

Since the major anticipated use of CAROM is policy gaming, the flexibility of simulation parameter specifications and report readability have been important design considerations. Simple input formats and self-explanatory reports, keyed to the major evaluation criteria of interest, have been designed for CAROM. Parameter card input formats have been designed so that they are simple to prepare; yet, they provide a good deal of flexibility. A concise summary report and several optional detail reports have been provided so that simulation results may be requested according to need.

C. OVERVIEW OF MODEL

CAROM is an entity simulation model that matures individual simulated airmen through monthly time increments, simulating losses, gains, promotions (both grade and skill level) and tour rotation over a period of up to 30 years. Airmen available for reassignment are optimally assigned by the model to a maximum of 112 discrete assignment categories within a single career area, where each assignment category is defined in terms of one of 28 grade/skill level combinations and one of four tour classifications (CONUS, Special, Accompanied Overseas and Remote).

The initial on-board manpower inventory and monthly gains to the inventory are input as individual simulation records from magnetic tape. All simulation-relevant characteristics for each individual are contained on these records. The initial condition of the inventory and subsequent accessions are, therefore, directly specifiable by the user.

Model control cards specify other policy parameters. Most parameters can be modified over the time interval being simulated. Therefore, model control cards carry an effective date specification to indicate the simulation month in which the policy parameters first apply. A separate control card module in CAROM processes all control cards and insures that policy parameters are fed to other modules on a timely basis during the simulation run.

During the simulation, individual model records are used to represent simulated airmen. Each simulation month, these records are processed individually by the model to determine whether the record is eligible for loss, promotion or rotation. If a record is eligible for any of these events, an appropriate CAROM simulation module simulates the event and matures the status of the simulation record as necessary.

Complete logical descriptions of the loss, gain and promotion simulation modules are given in Section D of this Chapter. Loss simulation includes exceptional attritions, non-reenlistments, early-out losses, retirements, up-or-out losses and CONUS overage losses. Gain simulation is accomplished via direct user inputs as described above. Promotion simulation by grade is accomplished in accordance with the Weighted Airman Promotion System (WAPS). Promotion simulation by skill level is done via a sampling technique from a user specified probability distribution for skill level promotions.

During the record maturation process, the assignment eligibility for each tour category is established for all airmen available for rotation. Eligibility data is tabulated by previous tour sequence and other deployability-related parameters including grade and skill levels, for use by the allocation module. After all records have been matured through a particular simulation month, the CAROM Allocator determines an optimal set of reassignments for rotation-available personnel. Following the allocation phase, the CAROM summary and optional detail reports are generated. The allocation results are then used to assign new tours to the simulation records of those airmen reassigned by the Allocator.

The following assignment policy objectives are optimally accommodated by the CAROM Allocator:

- Maximize the fill of up to 112 discrete assignment categories.
- Maximally adhere to user-specified shortage distribution policies in the event that manning shortages are inevitable.
- Maximize the number of assignments involving desirable tour sequences.
- Maximize the number of assignments "on-grade and on-skill level." If grade/skill level substitutions are necessary, maximize the number of most acceptable grade/skill level substitutions and minimize the number of least acceptable substitutions.

The optimal attainment of these objectives is a complex problem requiring sophisticated solution techniques. The allocation and assignment methodologies are described in detail in Section D of this Chapter, whereas a mathematical description of the assignment algorithms used is provided in Appendix A.

CAROM has a modular structure for the purpose of system efficiency and ease of system maintenance. Each major function of the model indicated above is performed by a separate module. A detailed description of this modular structure is provided by Chapter III. As an overview, the system may be viewed as comprising the following major modules:

- Control Card Processor
- Attrition Simulator
- Promotion Simulator
- Allocator Screen
- Allocator
- Report Generator.

The attrition, promotion and allocation simulators actually require two passes of the personnel records. Consequently, these simulators involve two modules each. On the same physical data pass one module "looks ahead" one month and performs a selection of appropriate records, while the second module simultaneously completes simulation processing for the current month on records that were selected on the previous data pass.

To provide insight into the processing sequence and mechanics of the model, it is useful to describe briefly the sequence of events during one pass of the internal and external data files. Figure 1 illustrates this sequence for a typical pass. As illustrated in Figure 1, a typical data pass (P_N) involves the following:

(1) Input all parameters in effect for the current time increment T_N and compute the promotion eligibility (WAPS score) cuts.

(2) For each new accession during the period, enter the necessary parameters in the corresponding record:

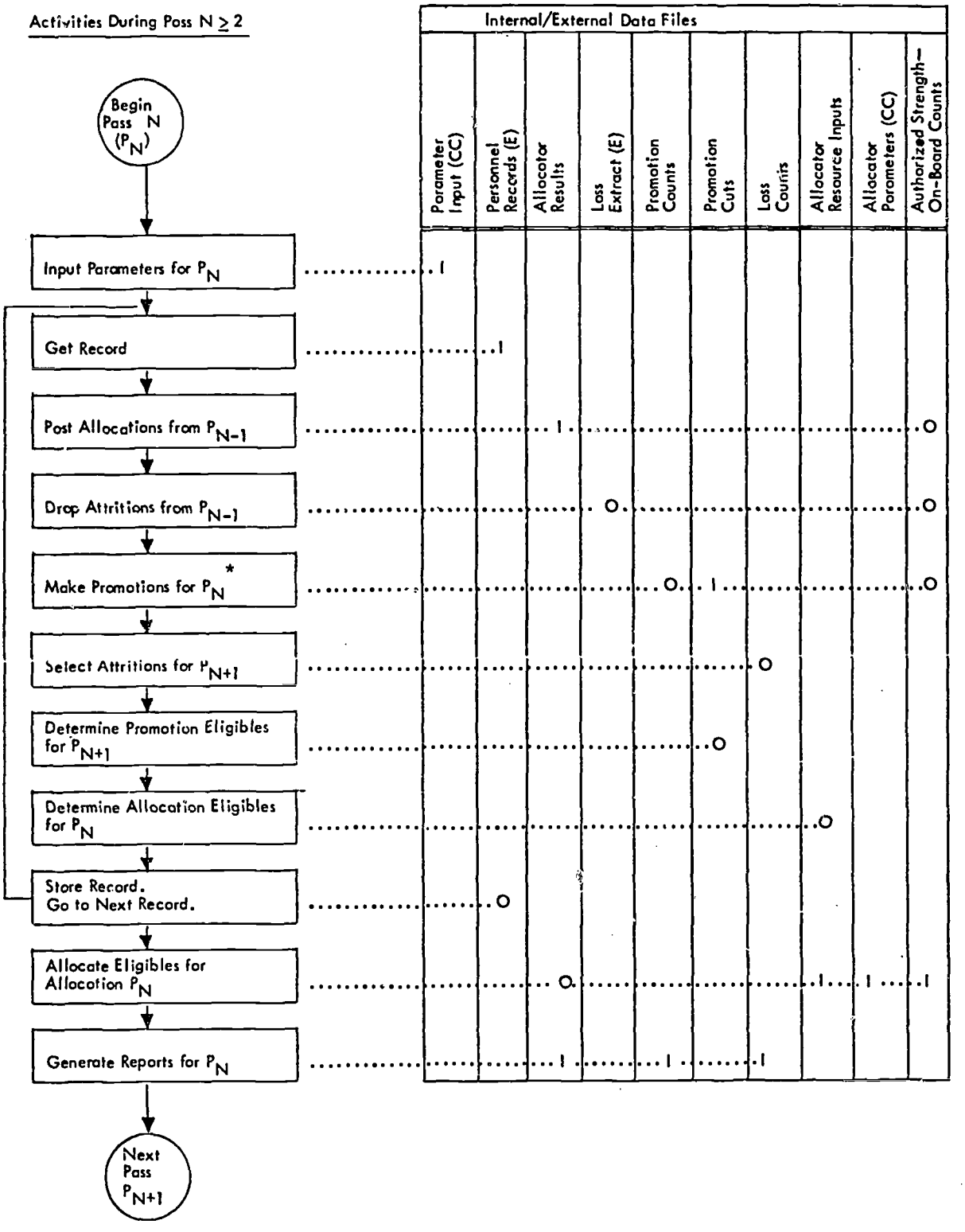
- expected exceptional attrition date (EEAD -- if any)
- availability for reassignment date (TCD)
- Availability for promotion date.

(3) For each on-board record perform the record updates resulting from the previous pass:

- post new tour category, billet grade, TCD, etc., for airmen who were reassigned during the previous pass (P_{N-1}).
- drop records who were selected during P_{N-1} for attrition from the active file and write these records on the loss file with the appropriate loss type code.

(4) Select grade promotions in accordance with the promotion eligibility cuts determined in (1) above.

Figure 1: MACRO FLOW CHART OF CAROM



Legend: I = referenced file is input to module.
O = referenced file is output from module.
E = external file.
CC = internal file produced by Control Card Processor.

* Grade level promotion is performed before skill level updating.

(5) Determine eligibility for skill level promotions and promote according to user-specified distribution.

(6) Select attritions, i.e., records to be dropped during the next pass, and accumulate counts.

(7) Determine the promotion counts for grade promotions in the next increment and store them for use on the next pass in computing the promotion eligibility cuts.

(8) Determine which records are available, and which are eligible, for reassignment.

(9) Perform an optimal assignment of these availables in accordance with manning requirements, airman eligibilities and user-specified policies.

(10) Generate reports applicable to period T_N and prepare for pass P_{N+1}.

The initial data pass (P_0) differs from the typical pass in that: (1) no record maturation is involved, and (2) the initial allocation involves only a determination of billet grade and skill levels for on-board personnel since no airmen are available for tour rotation. The next data pass (P_1) also differs from the typical pass in that no reassignments nor attritions were determined in the previous pass. A data pass is aborted after the Report Generator when T_{N+1} exceeds the user-specified length of simulation.

D. DESCRIPTION OF MODEL FUNCTIONS

The major functions performed by CAROM are the following:

- Simulation of career area gains and losses.
- Simulation of promotion, both by grade and skill level.
- Simulation of tour rotation.

Additional functions which must be performed within the model include the communication of data to and from the model user, i.e., the processing of user-

specified input variables, parameters and data records as well as the generation of reports and data files pertaining to the simulation results. To provide the necessary insights into the model, this section provides a detailed description of the three major model functions indicated above.

1. Simulation of career area gains and losses

One of the essential functions of any manpower/personnel simulation model involves simulation of gains and losses to the inventory. The manpower inventory of the CAROM model consists of personnel from one skill area. All simulation-relevant characteristics for each individual in the initial inventory are specified by the model user at the beginning of a model run. Thereafter, gains to the inventory consist of entry-level trained personnel entering either as "new accessions" -- at the E1/E2 grade level or beginning skill level (1/2) -- or as "prior-service accessions" at a given higher grade or skill level. Accession data includes all individual simulation-relevant characteristics and is specified by the model user on a by-month basis.

Losses from the inventory may be classified in the following categories:

— Involuntary attrition,

— Voluntary attrition, and

— Cross-training losses.

Involuntary attritions include "exceptional" attrition such as death, discharge, court-martial, etc. (also referred to as statistical attrition), and "forced" attrition. Forced attrition results from: (1) up-or-out policy attritions which preclude reenlistment for airmen who have not attained a given grade within a specified time in service, and (2) mandatory retirement at thirty years of service. Voluntary attrition includes ETS (expiration of term of service) losses due to non-reenlistment, early-out losses for first-term as well as career airmen, and early retirement

for career airmen with twenty or more years of service. Cross-training losses are used by the model to keep on-board inventory overages over the authorized strength within user-specified limits. Large overages could conceptually be accumulated under unusual model input specifications -- a situation which the model rectifies by randomly deleting airmen for cross-training purposes whenever the inventory exceeds the user-specified limit.

A detailed description of the model procedures with respect to gains and losses follows. In the model a particular record can become simultaneously eligible for more than one type of loss. When a simulation record becomes eligible simultaneously for more than one loss category, the order of loss simulation is as follows:

(1) Exceptional attrition

(2) Up-or-out losses

(3) Normal ETS losses or retirement (voluntary as well as mandatory)

(4) Early-out losses

(5) Cross-training losses.

a. Involuntary attrition

(1) Exceptional attrition losses

Losses due to death, compassionate discharges, court-martial, etc., are simulated by computing for each simulation record on entry to the model a date of exceptional attrition (EEAD). The EEAD is computed by a Monte Carlo process which compares a uniform random number generated for each record against a cumulative probability of survival. The cumulative probability of survival is based on a single monthly exceptional attrition rate specified by the model user. The generated EEAD is then stored as a permanent part of the simulation record. If the record is not lost due to other factors prior to its EEAD, it will be

lost as an exceptional attrition in the EEAD month.

(2) Up-or-out losses

Up-or-out losses in CAROM are simulated through the specification of a maximum time in service for each grade. Up-or-out losses occur when a simulation record reaches a reenlistment decision point (e.g., normal ETSD or an early-out reenlistment month) with a total time in service greater than or equal to the maximum allowable for its grade. When this situation is encountered, the simulation record is not allowed to reenlist nor to be promoted and is lost as an up-or-out loss at ETSD or early-out loss date.

(3) Mandatory retirement losses

Mandatory retirement losses are simulated in the model by deleting every record which accumulates thirty years in service at the 30-year point.

b. Voluntary attrition

(1) Normal ETS or early retirement losses

Normal ETS or early retirement losses are simulated in the model for a record in the simulation month of its estimated termination of service date (ETSD). A Monte Carlo process is used to determine retention or loss utilizing retention probabilities specified by years of service. If the record is not retained, it is lost in the ETSD month. If a record is retained, a new term of enlistment is computed for the simulation record from one of two 72-month reenlistment term probability distributions. The specific probability distribution used depends upon whether a first or subsequent reenlistment is being simulated. A new ETSD is then generated for the record by adding the computed term of enlistment to the old ETSD.

Normal term of enlistment simulation is suspended for airmen eligible for early retirement (i.e., personnel with twenty or more years of service). For such personnel a term of enlistment of one year is always generated. Therefore, retirement eligibles are subject to voluntary attrition at the twenty-year service point (e.g., simulation month 241 for those accessing in month 1) and at each subsequent one-year interval thereafter, until the thirty-year service point.[3] For career airmen with less than twenty years in service, the reenlistment term is always selected such that their time in service at reenlistment plus the new enlistment term is either less than or equal to twenty years. This feature allows a direct specification of percentage losses due to retirement by years of service.

Normal retention simulation as described above can also be interrupted in the following ways:

(a) If an early-out policy is in effect, retention simulation may occur prior to ETSD and the simulation record may be lost prior to ETSD as an early-out loss.

(b) When up-or-out policies are in effect, the new ETSD for a retained record will be such that the record does not accrue time in service beyond the maximum time in service point for its grade. Furthermore, any record reaching an ETSD greater than or equal to its maximum time in service month is always lost as an up-or-out loss.

(c) Retention simulation may occur at tour completion if required to establish rotation availability and eligibility. (See III, D, 3.)

[3] As described in Chapter II, Section D, 2, there is one exception to the one-year reenlistment rule for airmen eligible for early retirement. This exception applies to the minimum additional obligation which airmen may incur at promotion. If such obligation is more than one year and the airman is selected for promotion, the ETSD will be set according to the / obligation except when the new obligation would extend beyond thirty years. he latter case, the new ETSD would be the thirty-year service point.

(2) Early-out losses

Early-out losses are simulated in the model in two ways: (a) a general early-out policy based on months of obligated service remaining (for first-term airmen only), and (b) a tour completion early-out policy based upon tour completion (both for first-term and career airmen). The implementation of early-out policies causes retention simulation to be made prior to normal ETS. Non-retained records are then selected for early out according to specified percentages. Both types of early out simulation require two types of parameters:

— A maximum number of months of remaining obligated service to be eligible for early out (maximum time to do = MTTD).

— A percentage of eligibles for early out who will be allowed to early out (early-out percentage).

(a) General early-out policy (first-termers only)

A general early-out policy requires a single MTTD specification and an early-out percentage for each tour. When implemented, a general early-out policy causes all first-term retention simulations to be made in the first simulation month greater than or equal to ETSD - MTTD (normal reenlistment month minus maximum time to do).

If retention simulation results in reenlistment, then further simulation proceeds as described above under normal retention. If retention simulation results in non-reenlistment, a Monte Carlo comparison is made against the early-out percentage specified for the record's current tour. If the result of this comparison is less than the specified percentage, the record is lost as an early out

loss in the month of early out simulation. Records not selected as immediate early out losses are not eligible for subsequent general early out selection and will be lost at tour completion or normal ETSD.

(b) Tour completion early-out policy

A tour completion early-out policy requires a maximum time to do specification and an early-out percentage for each non-CONUS tour. Records assigned to a CONUS tour are never eligible for a tour completion early out. When a tour completion early-out policy is implemented, retention simulation occurs at the time a record completes a tour if it meets the maximum time to do eligibility requirement for the tour being completed. If the eligibility requirements are met, early out simulation occurs as described under the general early-out policy, i.e., Monte Carlo selection is made against the appropriate tour completion early-out percentage from those records whose retention simulation resulted in non-reenlistment. If selected, the record is lost as an early out loss in the month of tour completion. If the record is not selected for early out loss, it will be lost as a normal ETS loss at ETSD.[4]

If both general and tour completion early-out policies are in effect simultaneously, the following rules apply:

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[4] Airmen on a non-CONUS tour who have been determined to be lost at ETS may have their tours extended beyond the original TCD until the loss date if their time remaining (ETS-TCD) is less than a given parameter referred to as maximum time to ETS to be ineligible for transfer. These parameters are specified on card type 21 and should not be confused with the maximum time to do for early out. See Chapter II, section D, 3, Allocation screening.

(1) Retention simulation occurs only once in the first simulation month in which a record is eligible under an active early-out policy. If a record becomes eligible for both policies simultaneously, general early out selection is made prior to tour completion selection.

(2) Records eligible but not selected under a general early-out policy are subject to early out selection under a tour completion policy when and if they become eligible for tour completion early out.

(3) Records eligible but not selected for tour completion early out are not eligible for selection under a general early-out policy.

c. Cross-training

A single occupational specialty (career area), as simulated by CAROM, is subject to a special type of attrition resulting from airmen who are cross-trained into other career areas. Similarly, a special category of personnel gains may result from cross-training from other career areas into the one being simulated. Although the model is not designed to simulate such lateral flows across occupational specialties, certain model features will provide for a limited extent of cross-training simulation.

The model accepts accession records for prior service accessions. Thus, to the extent that the model user can specify records of airmen that are cross-trained from other career areas, CAROM accommodates cross-training into the skill area simulated by the model. The model deletes records in the event that CONUS overages exceed a user-specified percentage of the total authorized strength. Such records could be made available to other

career areas. Individual records deleted for the purpose of cross-training into another career area are randomly selected by grade and skill level from the CONUS tour in proportion to the CONUS overages by grade.

The cross-training loss feature is provided to avoid an unlimited growth in the CONUS overage category -- a situation which could cause difficulties for meaningful analysis and interpretation of model results. Large overages could occur if there is a cumulative imbalance between the normal gains and losses to the career area, or if there is a significant change in the authorized strength during the simulation period.

2. Simulation of Promotion

Promotion simulation in CAROM falls into two categories: (1) promotion by grade, and (2) promotion by skill level, generally referred to as skill level updating.

a. Promotion by Grade

Grade promotion simulation in the model is a three-step process. First, the records eligible for promotion during the simulation month must be determined. Second, the maximum permissible number of promotions must be computed for each grade to the next higher grade. Third, individual records to be promoted must be selected from the list of eligibles in each grade, in accordance with the appropriate selection policies.

(1) Promotion eligibility

To be determined eligible for promotion to the next grade, a record must satisfy four requirements:

- Attainment of minimum time in current grade
- Attainment of minimum time in service
- Attainment of minimum legal skill level for the next grade
- Time in service less than maximum allowed for current grade.

Minimum levels for each parameter are user-specified.

(2) Promotion ceiling

The maximum number of promotions to each grade is calculated according to one of two promotion quota systems: an equal selection opportunity system or a vacancy promotion system. In the equal selection opportunity system, the promotion quota, or maximum number of promotions (N_g), to each grade is calculated by the multiplication of a user specified proportion for that grade times the number of airmen eligible for promotion to that grade (E_g).

In the vacancy promotion quota system, the maximum number of promotions to each grade is a function of the authorized strength versus the on-board strength in that grade, overage and shortage in the higher grades, and the number of airmen eligible for promotion to the grade. The following equations define the maximum number of promotions, N_g, in a particular month from grade g-1 to grade g:

$$V_g = \frac{(A)\ (Q_g)}{100} - \sum_{j=g}^{9} B_j$$

$$N_g = MAX\left\{0,\ MIN\left(E_g,\ V_g\right)\right\}$$

Where:

g = Grade; g=3,...,9

A = Promotion strength (see footnote on page 32)

B_g = Actual on-board strength at the end of the simulation month for grade g

E_g = Number of airmen in grade g-1 eligible for promotion to grade g

N_g = Maximum number of promotions to grade g from grade g-1

Q_g = Maximum authorized percentages for grade g and above

V_g = Number of vacancies in grade g.

Application of the above formulas for each grade results in a ceiling on the number of promotions to each grade which is equal to the number of vacancies in that grade and above minus the on-board strength in that grade and above, subject to the number eligible for promotion. The total authorized strength, A, and the authorized percentages by grade and above (Q_g) are user specified input parameters.[5]

The actual numbers of airmen selected for promotion in CAROM may or may not be equal to the corresponding values of N_g depending on the outcome of the selection process described below. However, the model will never over-promote, i.e., the number actually promoted in the model is always less than or equal to the N_g as defined above.

(3) Promotion selection

Selection for promotion by grade is made according to the Weighted Airman Promotion System, based on a weighted composite score computed from the following eight factors (weight of each factor is user specified):

- TIS: Time in service, expressed in months. The maximum TIS for WAPS is 240.
- TIG: Time in grade, expressed in months. The maximum TIG for WAPS is 120.
- SKT: Specialty Knowledge Test, range 0-100.
- PFE: Promotion Fitness Examination, range 0-100.
- APR: Airman Proficiency Rating, range 0-90.
- DEC: Decoration score, range 0-maximum (user specified).
- Two as-yet-unspecified factors for future use.

[5] In the vacancy promotion system, CAROM allows the user to specify a "promotion strength" which may be different from the total authorized strength. The purpose of this feature is to permit promotion to the next higher grade above the highest grade authorized in the career area. For example, if E7 is the highest authorized grade within a career area, then promotion strength = authorized strength + desired strength of E8's. Once an individual is promoted to E8 he enters CONUS overage upon completing his current tour to be lost as a cross trainee. The desired strength of E8's can be found by either determining the total authorized strength in other career areas which is input from the career area being simulated, or by multiplying the Air Force wide authorized proportion of E8's by the authorized strength of the career area. For a career area that contains authorized E9's, promotion strength is equal to authorized strength for that career area.

A promotion selection methodology has been developed that, while not precisely replicating WAPS, provides results that are finitely close to exact WAPS simulation, while consuming significantly less time than the potentially excessive amount required by exact WAPS replication. The approach consists of computing a cut-off WAPS score for promotion to each grade such that, on the average, very close to the correct number (i.e., N_g) of airmen will be promoted. The airmen selected for promotion have a WAPS score above the predetermined cut-off score.

The method of computing the appropriate cut-off score is based on the realistic assumption that the WAPS scores of airmen eligible for promotion to each grade are normally distributed. Let:

X_{gi} = WAPS score of airman i eligible for promotion to grade g,

and using the same variables defined above, the mean WAPS score and its standard deviation in each grade set are:

$$\bar{X}_g = \sum_{i=1}^{E_g} X_{gi}/E_g$$

$$SD_g = \sqrt{\frac{E_g \sum_i X_{gi}^2 - (\sum_i X_{gi})^2}{E_g (E_g - 1)}}$$

The per cent of eligibles which may be promoted is also known:

$$P_g = \frac{N_g}{E_g}$$

In all practical cases, P_g is between 0 and 1 (if $P_g = 0$, there are no promotions and if $P_g = 1$ all eligibles can be promoted so that there is no selection problem). Thus, the problem is to find a score value

from a given, normal score distribution such that the area under the curve above the score value equals the given percentage P_g. This is a simple problem and is solved through finding the standard normal deviate associated with each P_g from a statistical table stored in the computer program. (The standard normal distribution has a mean of zero and a standard deviation of one.) This standard normal deviate, commonly referred to as z, is then transformed into the corresponding value of the given score distribution to find the cut-off value:

$$X_{cut} = z \cdot SD_g + \bar{X}_g$$ (Note that z may be positive or negative.)

This procedure insures that, on the average, the right number (N_g) of airmen will be promoted. But in any particular month, the number so selected may be less or more than N_g. To avoid over-promotion, the model therefore promotes all airmen with WAPS scores greater than the cut-off score until either the maximum number N_g has been reached or until that set of airmen has been exhausted. Consequently, the model may sometimes promote less airmen than maximally possible, but will never over-promote. Also, in the event that the N_g limit leaves certain airmen with a WAPS score above the cut-off score unpromoted, these airmen may include high scoring individuals as the approach does not entail sorting by WAPS score. Overall, it is believed that this promotion simulation process is realistic.

(4) Parameter Updating

Proper functioning of the Weighted Airman Promotion System requires periodic updating of the contributing factors, through re-examination and processing of each individual record at user-specified intervals. The first two variables, time in service and time in grade, are of course

continuously updated by the model -- these two are essential simulation related variables. With respect to the other WAPS factors, a statistical updating procedure has been devised.

Personnel data records input to the model have initial values for SKT, PFE, APR and the two as-yet-unspecified factors. At the user-specified intervals, these factors are updated, using the original value as the means and the user-specified standard deviation for each factor as the standard deviation for that factor. A normally distributed random number, generated accordingly, is used to determine each new score. The precise mechanics of the updating process are illustrated in Figure 2.

Updating of the number of decorations is simulated in a different way. Each time an airman completes a tour, a random number is generated from the appropriate user-specified distribution for that tour category to determine the decorations score awarded. This score is added to the current decorations score specified in the airman's record.

(5) Relationship to Loss Simulation

Individuals accepting promotions in certain grades may be required to guarantee a minimum obligated service time. CAROM simulates this event by accepting a user-specified minimum "promotion obligation time" parameter for each grade. If a simulation record is promoted without sufficient remaining obligated service time, its ETSD is set to the month of promotion plus the minimum promotion obligation time parameter for the new grade.

An exception to this rule occurs when the additional obligated time

Figure 2

PROCEDURE FOR GENERATING
TEST SCORES FOR SYNTHETIC RETEST CAPABILITY

Percentage of Normal Curve	URN Uniform Random Number Generated	Index to table (URN) (10) + 1.0 truncated at decimal	K	$K' = K\left[\sqrt{1-r}\right] SD_{test}$
0 - 9.99%	00 - .099	1	-1.6450	$(-.9010)SD_{test}$
10 - 19.99%	.1 - .199	2	-1.0365	$(-.5677)SD_{test}$
20 - 29.99%	.2 - .299	3	-.6745	$(-.3694)SD_{test}$
30 - 39.99%	.3 - .399	4	-.3854	$(-.2111)SD_{test}$
40 - 49.99%	.4 - .499	5	-.1256	$(-.0688)SD_{test}$
50 - 59.99%	.5 - .599	6	+.1256	$(+.0688)SD_{test}$
60 - 69.99%	.6 - .699	7	+.3854	$(+.2111)SD_{test}$
70 - 79.99%	.7 - .799	8	+.6745	$(+.3694)SD_{test}$
80 - 89.99%	.8 - .899	9	+1.0365	$(+.5677)SD_{test}$
90 - 99.99%	.9 - .999	10	+1.6450	$(+.9010)SD_{test}$

STEP

1. Generate Uniform Random Number, URN.
2. Multiply URN by 10.
3. Add 1.0.
4. Truncate at decimal point.
5. Look up K' in table (where r is test reliability = 0.70 by assumption)
6. Add old test score of individual.

NOTE: This procedure applies to all test scores comprising the Weighted Airman Promotion System (including the two scores currently undefined), except for the decorations scores.

would result in a total time in service greater than thirty years. As described previously (see Chapter II, section D, 1), every airman is deleted at the thirty-year service point under the mandatory retirement policy. Consequently, in such cases, the ETSD is set to correspond with the thirty-year service point. Airmen are not made ineligible for promotion because they would accrue additional obligation beyond mandatory retirement, i.e., their obligation beyond thirty years is waived.

However, an airman's eligibility for early retirement (twenty years or more in service) is affected by promotion obligations. During the period of additional obligation following promotion, normal eligibility for early retirement is suspended. Early retirement simulation resumes in the ETSD month as computed from the promotion month and obligated service time.

b. Skill Level Updating

All records of airmen entering the system will contain an initial skill level. (Skill levels 1 and 2 are grouped into one category, labeled S1/S2.) Both the legal skill levels and the legal grade/skill level combinations for each run are user-specified, and the system will check whether the grade/skill level combinations are within these boundaries, and provide diagnostic messages if necessary.

To be determined eligible for skill level "promotion," a record must satisfy two conditions:

(1) Minimum time in skill level must have been attained, and

(2) Promotion to the next skill level must be "legal" within the user-specified boundaries of legal grade/skill level combinations.

When a record does become eligible for skill level updating, the date of the next higher skill level will be determined by a random sampling technique from the user-specified probability distribution of the number of months from "attainment of minimum time in skill level" to "skill level promotion."

3. Simulation of Tour Rotation

The CAROM model simulates airman rotation flows among a maximum of 112 discrete assignment categories. The assignment categories are defined in terms of 28 grade/skill level combinations for each of four tour classifications.[6] Each of the 112 assignment categories (billets) has a specific authorized strength (i.e., manning capacity) against which on-board personnel are assigned for a specific period of time (tour length).

Each projection month simulated airmen complete tours of duty in each of the four tour categories and become available for reassignment to new tours. Airmen becoming available for reassignment simultaneously create vacancies in their previous tour categories. The CAROM rotation problem, therefore, becomes an allocation problem involving the assignment of available assets (available airmen) to billet spaces (vacancies by tour categories, and grade/skill level combinations).

The optimal solution to this problem requires that all assets be considered simultaneously for all billet vacancies. For this reason, allocation and tour rotation simulation in CAROM is accomplished in three parts:

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[6] The four tour categories used by CAROM are labeled CONUS, Remote, Special and Accompanied. The CONUS tour has uniquely defined properties with respect to rotation flow, but the Remote, Special and Accompanied tours (i.e., non-CONUS tours) all have similar rotation flow simulation characteristics.

(1) Individual simulation records available for assignment are collected and a determination of specific tour eligibilities is made for each record (Screening).

(2) Billet vacancies are computed, and an optimal allocation of eligible record types is made against billet vacancies (Allocation).

(3) The assignment results are posted to the eligible records, and a new tour completion date is computed for each reassigned individual (Posting).

Each of these simulation functions is defined in detail below.

a. Allocation Screening

An individual must be both available and eligible to be reassigned, and these concepts are independent. The availability of an individual is dependent only upon when he may be released from his current tour. The eligibility of an individual for a particular new tour depends upon the assignment prerequisites established for that tour.

(1) Availability

Individuals become available for reassignment on their tour completion dates (TCD). The TCD is established at the time an individual is assigned and may not be modified until the assigned TCD is reached. Tour completion dates are established differently for CONUS and non-CONUS tours.

For individuals assigned to a non-CONUS tour, the TCD is computed as the month of assignment to the tour plus a random tour length computed according to a tour length probability distribution specified for each tour. Each tour may have up to ten separate tour lengths, each with a separate probability. For new accessions to the model initially assigned to a non-CONUS tour, the record contains the TCD used in the model.

For CONUS tours, the TCD may be computed in one of three ways:

(a) New accessions

New accessions assigned to CONUS receive a TCD based on the TCD in their personnel record.

(b) CONUS returnees

For a user-specified proportion of the airmen rotated to CONUS from a non-CONUS tour, the TCD is computed exactly the same as for a non-CONUS tour: A given tour length distribution is used for random selection of a fixed tour length and the TCD is set equal to the month of assignment to CONUS plus the fixed tour length. The corresponding billets represent CONUS "fixed" or "stabilized" positions.

For the remainder of airmen returning to CONUS, the CONUS tour does not have a fixed duration. Accordingly, the TCD is not fixed but is computed in terms of a minimum time for deployment availability and a maximum time for deployment availability. The minimum time is determined as the month of assignment to CONUS plus the appropriate minimum CONUS time (which equals the least of the three user-specified minimum times in CONUS before deployment eligibility for each tour category). The maximum time is determined as the month of assignment to CONUS plus the user-specified maximum CONUS tour length.

(c) CONUS to CONUS reassignments

Upon reaching TCD (stabilized positions) or maximum tour length, airmen must be reassigned. If they are not reassigned to a non-CONUS tour, they must be reassigned in CONUS. Thus, airmen in CONUS left unused by the Allocator in the month of TCD or maximum CONUS time are reassigned in CONUS and have their TCD or minimum/maximum time for deployability updated. For this purpose, these airmen are treated just the same as returnees. A user-specified proportion is assigned to a fixed tour length (not necessarily the same airmen who had a fixed CONUS tour length before) with a new TCD computed accordingly, and the remaining airmen receive a variable tour length with a minimum and maximum computed as indicated above.

Normally an airman will always be available for reassignment at TCD. Three circumstances can cause a simulation record to be unavailable at TCD:

(a) Individual records may have their tours extended if they are close to ETS and will not reenlist. For each tour a "maximum time to do" to be available for reassignment is specified for first-term and career personnel. Any individual normally available for reassignment from a tour with less obligated service time than the maximum specified for transfer ineligibility will undergo reenlistment simulation at TCD (i.e., prior to ETS). If the simulation results in retention, that individual is available for reassignment and is processed as usual. If the reenlistment simulation results in non-retention, that individual's tour is extended to the loss date, and he is not available for reassignment.

(b) First termers (only) must have a certain "minimum time to do" to be eligible for a non-CONUS tour. If they have less time to ETS than the minimum specified, reenlistment is simulated prior to ETS. Those who will not reenlist have their current tour extended and are not available for reassignment.

(c) All parameters which establish CONUS availability for deployment (CONUS tour length, minimum/maximum time in CONUS, etc.) are dynamic in the sense that the model user may specify different values for different time periods of the simulation. Because TCD's once determined are never modified, input parameter changes may cause TCD's not to be in agreement with current policies for a limited time.

(2) Assignment Eligibility

Any individual available for reassignment is automatically eligible for reassignment in CONUS. Assignment eligibility for a non-CONUS tour is determined by tour category, using the following parameters:

(a) Impermissible tour sequences may be defined by tour. The tour sequence of an individual is defined by his previous tour, his current tour (i.e., the one he is leaving), and his next tour. Any tour sequence not ending in CONUS may be defined as permissible or impermissible.

(b) The assignment eligibility of an individual for a tour may be limited by the man's previous tour history defined in terms of the number of tours of a given type in which an individual has served and the date the individual completed his last tour of a given type. Specifically, each non-CONUS tour may limit assignment eligibility according to a maximum number of tours in each of the tour categories and by a "time since last tour" minimum for each of the tour categories. Maximum number of tours limits may be

established separately for first termers and non-first termers. Additionally, a minimum time in CONUS for assignment eligibility may be specified for each non-CONUS tour.

(c) Assignment eligibility for a non-CONUS tour may be limited for first termers not having more than a specified minimum number of months of remaining obligated service.

(d) Assignment eligibilities for any tour may be eliminated randomly according to specified percentages for each tour. Random eligibility elimination is provided so that factors influencing assignment eligibility but not specifically controllable may be accounted for, i.e., humanitarian exceptions, reclama factors, etc.

(e) For each tour and billet grade/skill level, a list of allowable substitutable grades and skill levels may be input to establish eligibility for this billet.

(3) Assignment Classification

A record's current and previous tour, grade, skill level and tour eligibilities uniquely classify the record with respect to allocation-relevant parameters. There are 28 possible grade/skill level combinations, eight possible combinations of tour eligibilities, and sixteen possible permutations of previous and current tours. Therefore, there are a maximum of 3584 possible classifications of rotation-available records.

As individual records are screened for assignment eligibility, they are tabulated by their resulting assignment classification into an

assignment availables vector. This vector of counts by type is then used by the Allocator to perform an optimal allocation of availables against billet requirements. The tabulation technique allows hundreds of thousands of records to be optimally allocated with a minimum of computational effort.

b. Allocation Approach

Assignment policies may be classified under two major headings, quota accommodation (fill) and quality accommodation (fit). Policies influencing distribution, the allocation of a shortage of availables with multiple eligibilities, fall within the grouping of fill policies. Policies influencing placement, the assignment of eligibles possessing certain desirable characteristics in preference to other eligibles who are less desirably qualified, represent fit policies. Fill policies are concerned exclusively with mandatory prerequisites for assignment. Fit policies concern themselves with desirable prerequisites -- prerequisites over and above those defining minimum eligibility.

The CAROM approach, therefore, includes a number of optimal solutions:

— an optimal solution to derive feasible quotas, accommodating user-specified shortage distribution policies; and

— one or more optimal solutions to accommodate multiple, conflicting assignment objectives associated with the "desirable" characteristics of availables.

The total problem may be viewed as having multiple objectives and, consequently, must be solved via a series of optimizations, each constrained by prior optimizations, and each imposing additional constraints on subsequent optimizations.

An optimal solution to the CAROM rotation problem requires that fill and fit policies be optimal for both on-board personnel in a tour and new assignees to the tour. To achieve the optimal solution, the CAROM Allocator assigns all personnel, both on-boards and new availables, simultaneously each month. On-board personnel in a particular tour category cannot be moved off their assigned tour, but can be reassigned to a new grade or skill level billet within the tour to achieve an overall optimal solution to the allocation problem. Tour shortages are shared in accordance with total authorized strengths in each billet and user-specified fill and fit policies are optimally applied to both on-board personnel and new assignees to a tour.

(1) Quota derivation objectives

The first stage of the CAROM Allocator determines feasible, i.e., achievable, quotas for each tour and grade or skill level category (billet). The objectives of this portion of the Allocator may be summarized as follows:

(a) The maximum utilization of on-board personnel must be achieved within billet authorized strengths and permissible grade and skill level substitutions.

(b) The maximum fill of billets must be achieved within the constraints imposed by the maximum utilization of on-board personnel, permissible grade and skill level substitutions, and the number and tour eligibilities of rotatable personnel.

(c) An optimal accommodation of user-specified shortage sharing policies must be obtained if manpower shortages occur.

(2) Shortage distribution policies

The model contains a flexible sharing policy approach which will optimally accommodate any shortage distribution policy. The approach used entails application of a primal-dual network flow algorithm in conjunction with a nonlinear optimization technique. The approach permits specification of absolute priorities for one or more assignment categories as well as proportional or disproportional sharing policies for assignment categories possessing identical priorities. The use of absolute priorities forces the algorithm to provide the maximum possible fill of a high priority category at the expense of lower priority categories. The model will allow any sequence of tour priorities, e.g., top priority may be given to filling the special assignment vacancies, followed in order by remote tours, accompanied overseas tours, and CONUS assignments. Sharing policies, on the other hand, are specified in terms of sharing coefficients, i.e., parameters which have been "captured" from an "ideal" distribution specified by the user. The sharing coefficients drive the assignment outcome to a "fair" or "unfair" sharing of shortages and provide optimal adherence to the user's desired ideal distribution of personnel to the various billets.

The sharing problem is nonlinear by virtue of the assumption that the greater a shortage in proportion to a quota (billet authorized strengths), the more vital the assignment of an additional individual. The "value" of assigning the "next" individual to a particular quota must be derived by a solution which considers the shortages for all quotas and the total number of remaining airmen. This nonlinear optimization problem is solved by the classical method of Lagrange multipliers (see Appendix A).

For a given set of sharing coefficients, the approach leads to a closed-form expression which cannot be solved explicitly. Therefore, an iterative approach, the Newton-Raphson procedure, is employed.

(3) Compensatory overages

The initial quotas used for each billet are equal to the authorized strength for the billet. Under normal simulation conditions, these quotas will accommodate personnel currently on-board in the tour. Under certain conditions, say a reduction in a tour's authorized strength during the simulation, not all on-board personnel in a tour may be legally assignable to the tour, i.e., the number, grade and skill level distribution of on-board personnel in a tour may not be accommodatable within the billet authorized strengths and the grade and skill level substitution policies for the tour.

On-board personnel that cannot be accommodated in authorized billets are treated as overages. Numerically, such overages must be absorbed as shortages by other billets in the tour category to avoid overfilling the tour with new assignees, i.e., to avoid assigning more total personnel to the tour than allowable given the total authorized strength for the tour. We shall refer to such shortages as compensatory shortages to distinguish them from shortages that result from the nonavailability of eligible new assignees for a tour category.

c. Quota Derivation

Because both compensatory and nonavailability shortages can occur in the CAROM rotation problem, feasible quotas are derived in two stages. Stage one maximizes the utilization of on-board personnel in each tour and distributes any compensatory shortages that may occur according to user-specified fill policies. Stage two maximizes the total fill of billets under

the stage one constraints and the eligibility of availables. Any additional noncompensatory shortages caused by nonavailability of qualified personnel are distributed such that total shortages, both compensatory and availability, are optimally distributed according to user policy. Stage two yields an optimal set of feasible quotas for the fit allocator.

For stage one, an initial quota equal to the authorized strength is established for each billet. For each tour category, an additional "overage" quota equal to the total number of on-board personnel in the tour is established. User-specified sharing coefficients and priorities are attached to each real billet quota. The overage quotas are given a priority lower than the minimum user-specified priority.

On-board assets for each tour are represented in stage one by a set of grade and skill level rows, one for each grade/skill level combination, with row availability quotas equal to the number of on-board personnel in each grade/skill level combination. An additional slack row for each tour is generated with a row quota equal to the total authorized strength for the tour minus the number of on-board in the tour, or zero if the total on-boards exceed the authorized strength for the tour.

On-board grade/skill rows are eligible for the overage quotas, and for billet quotas as defined by user-specified grade/skill substitution parameters. Any grade/skill substitution policy may be specified and different policies can be established for each tour. The slack row for each tour is eligible for all real billets of the tour but not the overage quota.

The stage one problem is optimally solved by the QUOTFIND Allocator (see Appendix A). QUOTFIND will maximize the number of on-board assignments for each tour and, if overages must occur, will establish the minimum overage quota for each tour and distribute the resulting compensatory

shortages according to the user-specified sharing policies.

The reduced quotas from stage one are used by stage two to allocate personnel available for rotation and maximize total billet fill. An additional CONUS overage quota equal to the total number of rotation-eligible personnel is established for stage two in addition to the stage one reduced quotas. The priority attached to the CONUS overage quotas is lower than all other priorities.

The on-board grade/skill rows from stage one (but not the slack rows) and the rotation-available personnel counts from the Allocator Screen are used as assets for the stage two allocation. The eligibility of the on-board grade/skill rows is established as in stage one. The eligibilities of the rotation-availables are established by the Allocator Screen and the user-specified grade/skill substitution policy. All rotation-availables are eligible for the CONUS overage column, but no grade/skill rows are eligible.

The QUOTFIND algorithm is used again to provide an optimal solution to the stage two problem. Any additional shortages resulting from a nonavailability of eligible personnel are added to the compensatory shortages distributed in stage one, and the total resulting shortage is distributed optimally with respect to user-defined policies. If rotation-available personnel cannot be accommodated within the total authorized strengths and eligibility constraints, they are assigned to the CONUS overage column.

The reduced quotas from stage two represent the optimum feasible set of quotas for the fit optimization phase. It is emphasized that when overages occur, either of the on-board type or a CONUS overage, the QUOTFIND Allocator establishes the number of such overages, but does not determine which specific assets are to be considered overages. The determination of

which assets are overages depends upon the user-specified fit policies, and will be determined by the OPTIMIZE Allocator.

d. Fit Policy Accommodation

Following maximum accommodation of quotas, the model employs a successive surface optimization technique to optimally rearrange assignment such that the number of assignments meeting desirable objectives is maximized without altering in any way the fill of quotas obtained by the quota accommodation phase (details of the successive surface optimization technique utilizing the OPTIMIZE algorithm can be found in Appendix A). The model accommodates desirable policy configurations, maximizing preferred assignment action, i.e., minimizing the extent of grade and skill level substitution in assignments and maximizing the number of desirable tour sequences in assignments. Up to thirty-five different desirable configurations of tour sequence, grade and skill level substitutions may be specified for each billet.

(1) Parameter specification

To achieve the optimal solution, a rank order from 1 to 35 is attached to each legal combination of grade, skill level and tour history sequence. Tour history sequences are defined by an airman's previous and current tours. There are sixteen possible tour sequences and 28 possible grade/skill level combinations; thus, there are 448 possible grade/skill level/tour sequence combinations. Each billet may define any number of these combinations as desirable fit attributes in any of the thirty-five possible rank orders.

User fit policy is established in the following manner on initial model input cards:

(a) A specification of eligible tour sequences is made by tour in decreasing order of desirability. In subsequent data references, the most desirable tour sequence is defined as the "A" sequence, the second most desirable as "B," etc.

(b) For each tour, a separate list of eligible airmen's grade/skill level combinations (in order of descending desirability) is given to each billet grade/skill level. In subsequent data references, the most desirable grade/skill level combination for a billet is referred to as the "A" grade/skill level; the second most desirable as "B," etc.

(c) A third specification defines for each tour and grade/skill level (billet) the desirable combinations of grade, skill and tour sequence for each rank order level. The specification is made by specifying the lowest-ranked (least desirable) grade/skill level combination and tour sequence allowable for a level. All higher-ranked grade, skill and tour sequences are also considered desirable at the specified level.

The fit specifications are made using a letter designation (A to T for grade/skill level combinations and A to P for tours) corresponding to the position of the grade/skill level, or tour sequence, in the previously defined eligibility tests. For example, BA refers to either of the first two most desirable grade/skill level combinations combined with the most desirable tour sequence.

One two-letter specification can be made for each of the 35 rank order levels for each billet. For example, for any remote tour billet, the user might define the first two rank order levels as: level 1, A (grade/skill level), A (tour); level 2, B (grade/skill level), A (tour); level 3, B (grade/skill level, D (tour). This specification is interpreted

as: Fill the Remote tour billets with the maximum number of personnel with the most desirable grade, skill and tour sequence. If it is not possible to fill billet requirements with such personnel, assign the maximum number of personnel with the second most desirable grade/skill level combination and most desirable tour sequence. If billet requirements still cannot be filled, fill the remaining billet spaces with personnel of either of the first two most desirable grade/skill level combinations and any of the first four most desirable tour sequences.

The last specification above is an example of equally-weighted tour history sequences, i.e., tour sequences B, C and D have been weighted equally at the third level (the number of assignments with tour history sequence A was previously maximized at level 2).

(2) Successive optimization

The Fit Allocator maximizes the accommodation of user fit policy through a successive surface optimization technique. Each rank order level of desirable substitution defined by the user represents a separate policy optimization problem and, therefore, up to 35 optimal assignment allocations are performed to determine the final assignment outcome. Each optimization is constrained by the optimal solutions that occur prior to it, and further constrain the optimal solutions that occur after it.

Successive surface optimization is used because there is generally more than one level of desirable substitution policy, each of which defines a separate allocation problem to be solved. The primal-dual network flow solution used to solve each fit allocation problem determines not only an optimal arrangement of assignments under a given substitution policy, but also generates a "residual matrix" which defines the

permissible optimal assignments for each airman in the assignment problem under a particular fit policy. This matrix may be used to constrain successive policy optimizations.

Conceptually, the following sequence of operations is performed by the Fit Allocator during successive surface optimization:

(a) The initial eligibility matrix from the Allocator Screen and the final set of feasible quotas from the Fill Allocator are input by the Fit Allocator.

(b) The first assignment desirability bits vector[7] is input, and an optimal allocation is performed to maximize the number of assignments on the first (most desirable) policy level within the eligibility constraints and quotas.

(c) Using the residual matrix from the first allocation, the original eligibility matrix is modified by removing non-optimal eligibilities. The new matrix thus formed becomes the eligibility matrix for the second policy optimization problem.

(d) Steps b and c are repeated for each of the 35 possible surfaces (or as many as are defined, if not all 35 possible rank orders are used). The allocation made on the final surface represents an optimal solution to the rotation problem given all fit and fill policies and is, therefore, final Allocator output to the posting and reporting sections of the model.

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[7] The Control Card Processor transforms the fit policy specifications into a set of up to 35 bit vectors specifying the desirable assignment combinations for each billet. For allocator rows representing rotation-available personnel, the tour, grade and skill specifications determine billet desirability. For rows representing on-board personnel, only grade/skill parameters are used to determine billet desirability since the tour history specification is not meaningful for such personnel.

Although the conceptual approach outlined above is accurate, in practice, a number of computational steps are added to improve the Allocator's efficiency. Two of these are particularly important. First, the specific assignment solution produced from each optimal solution is used to initialize the succeeding solution to avoid redundant initialization computations. Second, any columns or rows whose assignment solutions become unique after a particular optimization (i.e., cannot be improved) are removed from the succeeding problem.

e. Record Posting

Following the allocation of the personnel available counts, the assignments made by the Allocator are output to peripheral storage for use by the Report Generator and the Allocation Posting modules of CAROM. The Report Generator uses the allocation results to produce the manning level reports. The Allocation Posting module uses the Allocator assignments data to assign new tours to personnel simulation records.

The record posting operation occurs in two steps:

(1) Following the allocation and prior to the next pass of the simulation record data base, the Allocator assignments file is input and restructured to the proper format for the posting process. Assignments to the CONUS overage quota are used to generate the grade/skill distribution of CONUS overages for use during cross-training loss simulation. The row assignments are then compressed by using the row numbers (previously generated) for the purpose of providing the necessary tour, grade and skill information.

(2) On the next pass of the simulation records, individuals tabulated for assignment on the previous pass are merged with the compressed Allocator results. Each record being reassigned is given an appropriate new tour, tour history data is updated, and a new TCD is computed for the record as described previously (see Chapter II, Section D, 3, a).

III. SPECIFICATION OF SYSTEM MODULES

The previous chapter described in detail the major functions of CAROM:

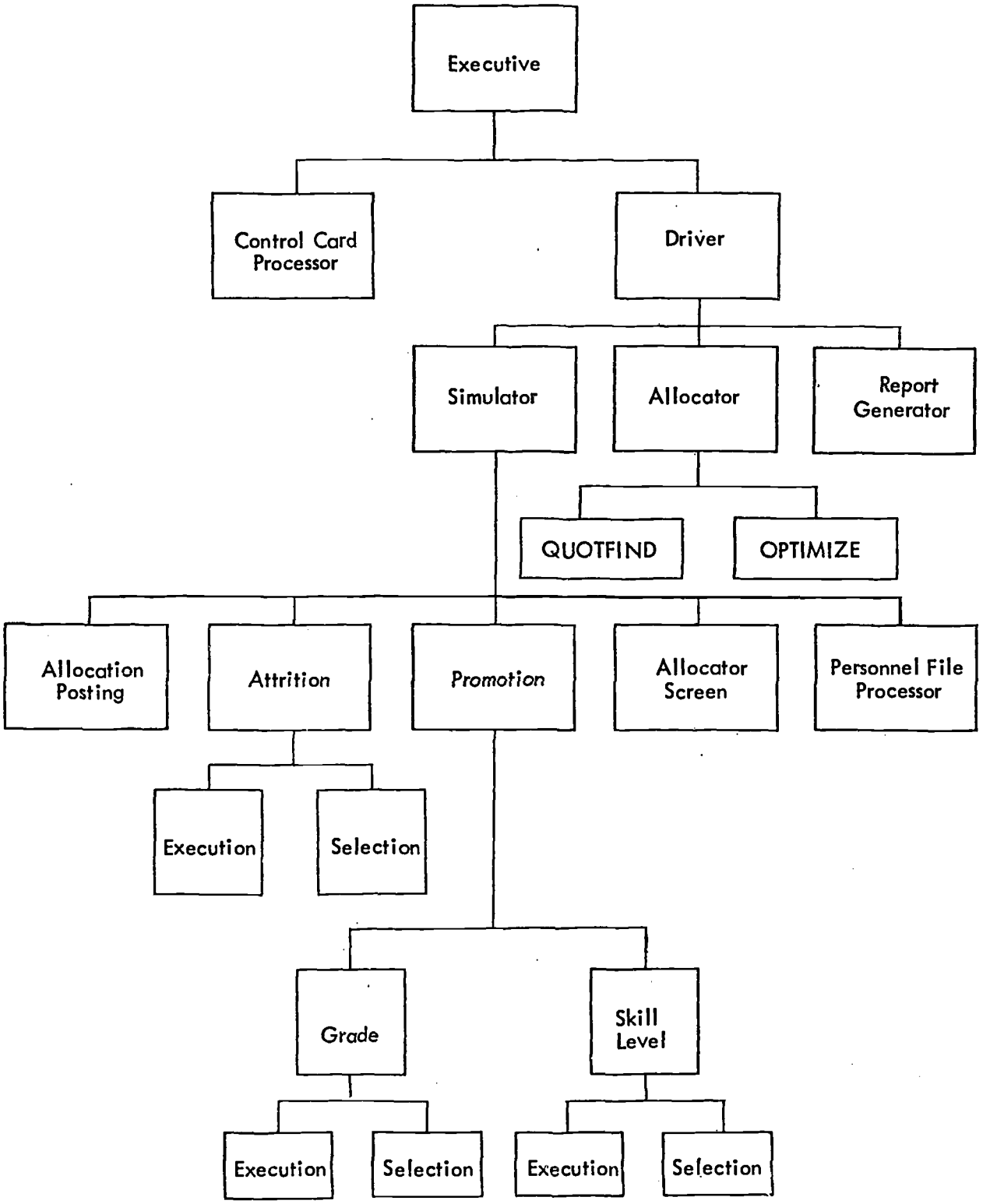
- Simulation of gains and losses
- Simulation of promotion
- Simulation of tour rotation.

These functions are performed in the system through several separate modules. A variety of additional modules is necessary for processing the model input, for controlling the flow of data throughout the system and for generating the CAROM reports and data files. The entire modular structure is illustrated in Figure 3, whereas the internal data files for communication between the various modules are indicated in Figure 4.(see page 68).

CAROM consists of two overlays: one overlay contains the Control Card Processor and the second overlay contains the entire rest of the model. A small section of computer code, referred to as MAIN, is provided to control the overlays and to provide data communication within central memory between the two overlays. All other modules contain a sizeable amount of computer code and will be described in this Chapter in the following order:

- Control Card Processor
- Driver
- Simulator
- Allocation Posting Module
- Attrition Simulator
- Promotion Simulator
- Allocator Screen
- Personnel File Processor
- Allocator
- Report Generator.

Figure 3: Modular Structure of CAROM



As indicated in Figure 3, most of these modules comprise, in turn, two or more submodules which, in turn, may comprise several different subroutines. The purpose of this Chapter, however, is not to provide the level of detail which may be required for system maintenance but to provide sufficiently detailed information so that the model user understands what the system does and, in general terms, how the system works. Therefore, the above breakdown is deemed adequate for this purpose. The description of each module contains the following information:

- purpose
- input
- output
- functional relationships
- summary of operations.

The detailed logic of those operations which are of essential interest to the user have been described in Chapter II.

A. CONTROL CARD PROCESSOR

1. Purpose

The purpose of the Control Card Processor is to process, validate and distribute to internal and external files the data contained in the control cards submitted by the model user. In the process of redistribution, all parameters are reformatted and stored in a form suitable for rapid processing in the other sections of the model. An additional function of this module is to generate the control card listing and any input error diagnostics as may be required.

2. Input Description

The input consists of all control cards which are described in detail in Chapter IV, section A. These control cards define all parameters used by the model except the personnel data. The control cards and the data they contain may be divided into two categories, permanent data (card types 01-07) and dynamic data (card types 08-25), and are briefly summarized below.

Permanent data remain valid or constant throughout a simulation run and include the following:

- Run parameters (simulation length, reports requested, level of discrimination)
- Legal skill levels and grade/skill level combinations
- Tour sequence desirability
- Grade/skill level substitutions
- Desirability level definitions (by tour category/grade/skill level)
- Distribution policies (priorities and sharing coefficients)
- WAPS updating parameters.

Dynamic data may be varied during a simulation run and, therefore, are specified by date (i.e., simulation month) of applicability. These data include:

- Miscellaneous parameters such as total authorized strength, exceptional attrition rate, maximum CONUS excess and parameters governing deployability such as minimum time in CONUS, maximum CONUS tour length and per cent of CONUS returnees in stabilized positions.
- Minimum time in grade for promotion
- Minimum time in skill level for promotion
- Minimum time in service for promotion
- Weights for WAPS factors
- Time distribution for skill level promotion
- Distribution of reenlistment terms (for first-term and career airmen separately)
- Minimum obligation upon promotion
- Retention rates by years in service
- Up or out policy (maximum time in service by grade)
- Authorized strength by tour category/grade/skill level as proportions of total authorized strength
- Tour length distribution for each tour category (including stabilized CONUS positions)
- Deployment eligibility parameters: for each tour category, minimum time since last tour, minimum time to do for first-termers, maximum time to ETS, maximum number of tours and proportion ineligible for transfer

- General early out policy: maximum time to ETS for first-termers to be eligible, and the proportions of first-term eligibles to be receive early outs by tour category
- Tour completion early out policy: maximum time to ETS and the proportion of eligibles to receive early outs by tour category
- Decorations distribution: the distribution of the decoration score awarded at tour completion by tour category
- Promotion strength: the numbers of airmen authorized by grade in the career area being simulated.

3. Output Description

Output from the Control Card Processor includes the following external and internal data files:

External:
- Control card listing
- Error diagnostics

Both files are stored on tape 8 for off-line printing. The first file lists all control cards as submitted by the model user. The second file contains any error diagnostics as necessary. The content of both listings is further discussed in Chapter V under Operator Output.

Internal:
- All permanent data excluding those pertaining to assignment eligibility and desirability are stored in COMMON (central memory).
- All dynamic data are stored on disk file 5.
- All assignment eligibility/desirability data are stored on disk file 6 in the form of bits (column vectors) indicating assignment eligibility/desirability by level of desirability by assignment category (tour/grade/skill level).

4. Function Relationships

The Control Card Processor has sole responsibility for the input to the model and the establishment of the basic simulation parameter files. Consequently, this module interacts strongly with the other sections of the model, particularly the simulation modules. The permanent data file stored in COMMON is transmitted through MAIN to the second overlay where the data is utilized by the Simulator, the Allocator, as well as the Report Generator. The dynamic data file is utilized by the Simulator and the allocation parameter file by the Allocator Screen and the Allocator.

5. Summary of Operations

The Control Card Processor consists of three sections. One section reads the input data from the control cards, the second section writes the data files (COMMON and disk file 5) and any error diagnostics, while the third section creates the eligibility and assignment deployability vectors stored on disk file 6.

The control cards are processed in sequential order. No sorting operations are performed so that the cards must be in the proper order (i.e., by month of applicability starting with month "0"), otherwise the run will be aborted with the proper error diagnostics. Other tests designed to insure data accuracy are apparent from the discussion of error diagnostics (see Chapter V, section C).

B. DRIVER

1. Purpose

The Driver initializes, sequences and terminates all model activities except the processing of control cards. It processes the personnel data records, generating any error diagnostics as may be called for; it monitors the Simulator, Allocator and Report Generator; and it updates the simulation clock. The Personnel Status File records generated by the Driver contain similar information as the input personnel data records but in a different format and code (binary). The sole exception is the computation of an exceptional attrition date (if any). Additionally, it computes certain parameters required for the simulation of promotions and attritions, and it maintains a running count of the inventory. When the simulation is terminated, the Driver returns control to the CAROM Executive (MAIN) where the run is terminated.

2. Input Description

The Driver inputs the Personnel Records prepared by the model user. For each airman (both those in the initial inventory as well as those entering the model during the simulation), these records contain the following data:

- Month of first enlistment
- Month of ETS
- Grade and skill level
- Month of rank and number of months in skill level
- Current tour category
- TCD
- Assignment history: by tour category, the number of tours and most recent TCD

— WAPS factors: SKT, PFE, APR, Decorations and two other (unused) factors.

All date information is relative to time zero, the month in which the simulation is started. The month of entry of future accessions is established through the sequence on the input tape.

Additional input includes the following:

— Permanent and dynamic simulation parameters.

— Attrition counts: the number of airmen by grade to be lost in the current month as determined by the Attrition Simulator during the previous pass.

— Promotion counts: the number of airmen by grade to be promoted in the current month as determined by the Promotion Simulator during the previous pass.

3. Output Description

The Driver writes the personnel records onto a Personnel Status File in a recoded, binary format for further processing by the Simulator. This file is stored, alternately, on tapes 1 and 2. Records pertaining to the projected inventory have been written by the Personnel File Processor, while the Driver adds the records pertaining to the current month's accessions.

Each record on the Personnel Status File consists of four words of 60 bits each for each airman. The binary format and data content is illustrated in Figure 5 (see page 69). For the records of new accessions output by the Driver, some of the data fields are blank, while for the on-board inventory, previously processed by the model, such data fields contain an entry. While processing the personnel data records input by the user, the Driver also generates error diagnostics in the event input records contain faulty data.

In addition to the personnel status records, the Driver provides the following output parameters for use in other modules:

- Accession count: the number of new accessions for the current month.
- WAPS cut-off scores: the minimum WAPS score for promotion to each grade in the current month.
- Promotion ceilings: the maximum possible number of promotions to each grade in the current month.
- CONUS excess counts: the numbers by grade in excess of the user-specified allowable CONUS overage.

4. Function Relationships

The Driver schedules the data flow within the model between the various modules in the second system overlay, but has little direct effect on their operations. The only exceptions consist of the parameters establishing promotability (by grade) for use in the Promotion Simulator, the CONUS excess counts (if any) for use in the Attrition Simulator, and the computation of the exceptional attrition date (EEAD) entered in some of the records. Further, the Driver controls the simulation clock indicating the current month of simulation. It returns control to MAIN when the simulation is terminated at the user-specified length of simulation.

5. Summary of Operations

a. Accessions for the current month are input from the Personnel Data File (file 9) and a counter accumulates the number accessed.

b. Reformatted records of these accessions are output on the back of the Personnel Status File (file 1 if current month is odd or file 2 if it is even), while simultaneously an EEAD is determined for those airmen who will be lost due to exceptional attrition.

c. The Personnel Status File is rewound to the beginning (the first part containing the personnel inventory matured through the current simulation month).

d. The simulation clock is increased by one (month).

e. The promotion parameters (WAPS cut-off scores and promotion ceilings) are computed in accordance with the formulas given previously (see Chapter II, section D, 2).

f. The CONUS excess counts (if any) over and above the user-specified allowable overage are computed as follows. Total inventory at the end of the current month equals that of the previous month plus the accessions of this month minus the total attritions this month. A comparison of the number against the authorized strength plus the overage allowed determines the excess to be lost this month. This excess (if any) is spread to grades in direct proportion to the CONUS overage category as determined in the last previous allocation. (The CONUS overage category simply comprises the slack columns in the Allocator.)

g. The main iterative sequence is entered, inputting one status record at a time until all records have been processed. This sequence consists of the operations described in sections C through H below and terminates with a totally-updated personnel status file stored on the alternate physical file.

h. Following completion of the maturation process, the Allocator is called to perform an optimal assignment of all airmen available for reassignment.

i. Following the assignment solution, the Report Generator is called to produce the necessary reports whereupon the process is continued with step a above until the end of the simulation has been reached.

j. If the end of the simulation period has been reached, the Report Generator has to perform additional operations after which control is returned from the Driver to MAIN which terminates the run.

Notice that for the initial inventory (simulation month zero), the main iterative sequence, in part, is followed (bypassing certain modules) because the modules involved look ahead one month, establishing information pertaining to next month's attritions and promotions. For this first pass of the Personnel Status File (initial inventory only), the following modules are bypassed in step f above: Allocation Posting (section D), the Execution submodules of the Attrition Simulator (section E) and of the Promotion Simulator (section F), and the Personnel File Processor (section H).

The Report Generator is called after the initial on-board assignment to produce the Monthly Summary Report (only) documenting the initial allocation solution.

Figure 4: INTERNAL AND EXTERNAL DATA FILES

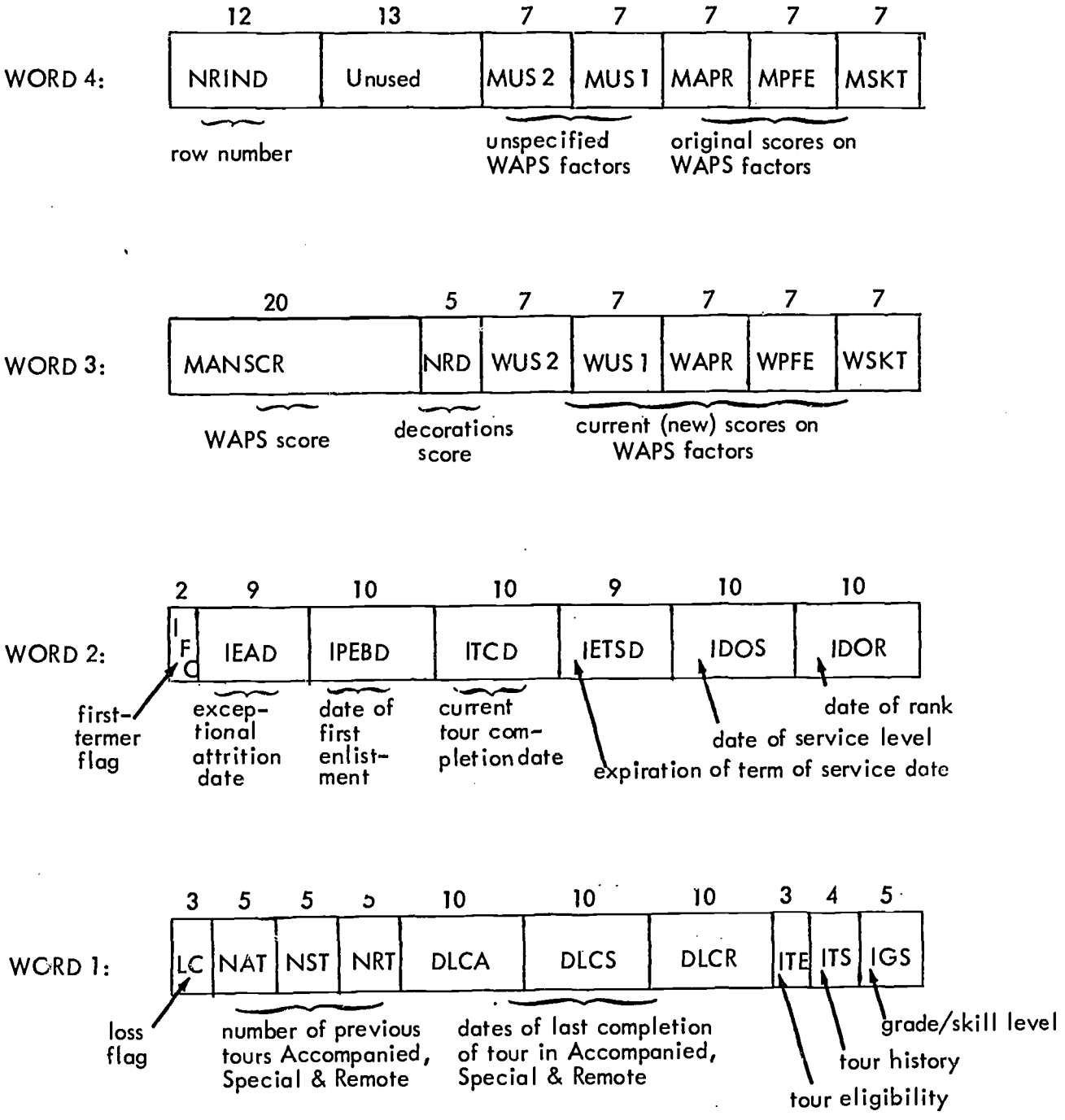
File Identification	Content Description	CAROM Module: Control Card Processor	Driver	Simulator	—Allocation Posting	—Attrition	—Promotion	—Allocator Screen	—Personnel File Processor	Allocator	Report Generator
External input	Control Cards	I									
	Personnel Status Records		I								
1	Personnel Status File (odd months)**		O	I					O		I*
2	Personnel Status File (even months)**		O	I					O		I*
3	Loss File								O		I*
4 (Ext)	Detailed Reports File										O
5	Dynamic Simulation Parameters	O	I	I	I	I	I	I		I	I
6	Column Eligibility/Desirability Vectors	O								I	
7 (Ext)	Loss File/Final Status File										O*
8 (Ext)	Control Card Listing/Error Diagnostics/Summary Reports	O	O								O
Central Memory	Permanent simulation parameters	O	I	I	I	I	I	I		I	I
	Accession count		O								I
	WAPS cut-off scores		O				I				
	Maximum number of promotions		O				I				
	CONUS excess counts		O			I					I
	Personnel records			O	I/O	I/O	I/O	I/O	I		
	Attrition counts		I			O					I
	Promotion counts		I				O				I
	Row counts							O		I	
	Vectors of row numbers				I			O		I	
	Vectors of new assignments				I					O	I

Legend: I = Input to module indicated
O = Output from module indicated

* Final simulation month only.

** The Personnel Status File output by the Personnel File Processor is the alternate file from the file input for that month to the Simulator, whereas the Driver adds the new accessions in that month to the back of that file prior to the next pass.

Figure 5: BINARY FORMAT OF INTERNAL PERSONNEL STATUS FILE



NOTE: For up to 28 legal grade/skill level combinations, five bits are necessary for specification of a particular grade/skill level. For four tour categories, there are 16 different sequences of two tours (previous and current tour), requiring four bits for specification of a specific tour history. Similarly, the tour eligibilities range from zero (= CONUS only) to seven (S, R or A only, or in various combinations), requiring three bits for specification of specific tour eligibilities.

C. SIMULATOR

1. Purpose

The function of the Simulator is to initialize, sequence and terminate the record maturation processes. It processes one status record at a time and monitors the Allocation Posting Module, the Attrition Simulator, the Promotion Simulator, the Allocator Screen and the Personnel File Processor. Additionally, this module updates the individual WAPS factors in each record at user-specified updating intervals. After all records have been processed for the current month, control is returned to the Driver.

2. Input Description

a. Personnel records (one at a time) from file 1 or 2.

b. Simulation parameters from file 5 and through COMMON.

3. Output Description

One personnel record (in COMMON) with updated WAPS factor scores.

4. Function Relationships

The Simulator schedules the data flow within the model between the various simulation and record updating modules, but has little direct effect on their operations. The sole exception is that it updates the WAPS factors at user-specified intervals. (As a matter of fact, the Simulator is a segment of the Driver and not a separate module; it is discussed as a separate module only for ease of presentation.)

5. Summary of Operations

a. One record is read from file 1 or 2 (for record content, see Figure 5).

b. If the current simulation month is one user-specified interval from the last previous time the WAPS factors were updated, these factors are

updated again in accordance with the logic described in chapter II, section D, 2. This computation is based on a normal distribution of the factor scores (SKT, PFE, APR and the two unspecified factors) with the original scores as means and standard deviations as specified by the user on card type 7. Consequently, it is necessary to keep in each man's record both the original scores and the current scores.

Initially, the assumption is that all factors have been updated in month zero. For example, if the user-specified interval is twelve months, WAPS factors are updated in all records present at the 12th, 24th, etc., month of simulation.

c. The main iterative sequence is entered, consisting of calls to the Allocation Posting Module, the Attrition and Promotion Simulators, the Allocator Screen and the Personnel File Processor, described in sections D through H below. All these modules operate on one personnel record in COMMON and make record updates as necessary.

d. Upon completion of this sequence, the Simulator continues with step a above, reading the next personnel record from the file until all records have been processed.

e. After all records have been processed, control is returned to the Driver.

D. ALLOCATION POSTING MODULE

1. Purpose

The sole function of this module is to update the records of those airmen who have been reassigned by the Allocator on the last previous pass. The update consists of replacing the current tour category and tour completion date by the new tour category and tour completion date, and modifying the assignment history data fields accordingly.

2. Input Description

a. One personnel status record.

b. Permanent and dynamic simulation parameters.

c. Vector of row numbers.

d. Vector of assignments.

3. Output Description

One personnel record with updated status information on:

— Current tour

— Tour completion date

— Number of previous tours in current tour category

— Tour completion date for most recent tour in previous tour category

— Tour history (previous and current tour)

— Decorations score.

4. Function Relarionships

This module provides an interface between the Allocator and the internal Personnel Status File, utilizing information previously stored in central memory pertaining to the assignment solution outcome as well as the necessary simulation parameters.

5. Summary of Operations

a. First a check is made whether the present record needs updating or not. This is easily determined via the row number stored in the record (the row number was previously computed by the Allocator Screen and entered into the record; see section G below). If the row number is larger than a certain threshold value, the record was not eligible for transfer in the previous month so that it was not reassigned and no tour updating is necessary. The threshold value depends on the number of legal grade/skill level combinations specified by the user for the current run. For example, if this number equals the maximum number allowed in the model, which is 28 grade/skill level combinations, then the threshold value amounts to 128 x 28 = 3584 (see Figure 6 for the formulas used by the Allocator Screen for computing the row numbers).

b. If the row number is less than or equal to the threshold value, the record may have been reassigned. The current assignment (tour category) is found by entering the vector of row numbers (put out by the Allocator after last month's assignment and stored in central memory) at the appropriate row number where a record pointer is stored identifying the corresponding location in the vector of assignments. This vector (also produced by the Allocator after last month's assignment and stored in central memory) contains the tour categories of all rows (airmen with the same assignment characteristics: grade/skill level, tour history and tour eligibility) considered by the Allocator for reassignment. If the tour category thus found is different from the current tour category carried in the record, an update is made. Otherwise, if the two tour categories are identical, the airmen was not reassigned and no update is necessary unless the tour category is CONUS, in which case an update may be necessary.

c. In the first case (reassignment), a new TCD is computed and entered into the record, the old TCD is moved to the data field for the most recent TCD of the airman's previous tour category, the new tour category is entered in the record replacing the previous tour category and the count of the number of previous (including present) tours in the current tour category is incremented by one. The computation of the new TCD is in accordance with the logic described in Chapter II, section D, 3. If the new tour category is non-CONUS, there is no problem. If it is CONUS, a random number is generated to determine whether the airman is assigned to a "non-fixed" or "fixed" (stabilized) CONUS position. If it is a "fixed" position, the TCD is determined just like for a non-CONUS tour. If it is a "non-fixed" position, a TCD cannot be determined because the tour length is subject only to a certain minimum and maximum CONUS time. In that case, instead of a TCD the month of arrival in CONUS (Date Arrived U.S. or DAUS) is entered into the TCD data field (see Figure 5 where the field is identified by ITCD). The Allocator Screen (see section G below) will identify the airman as filling a non-fixed position and will determine his availability for reassignment by subtracting the DAUS from the current simulation month and comparing the difference against the given minimum times in CONUS for each non-CONUS tour category.

In the second case (previous as well as current tour category is CONUS), the airman's record may still have to be updated in the event that he has reached the maximum CONUS tour length. The Allocation Posting module determines whether this is the case or not. If the airman has reached the maximum CONUS tour length, he is reassigned in CONUS and the same

operations are performed as described above: decision whether it is a fixed or non-fixed position, computation of TCD and entering the new TCD or the DAUS in the man's record, and updating the tour history data.

d. For each airman reassigned to a new tour, the number of decorations awarded at tour completion is computed and added to the current number in his record. The number awarded is drawn randomly from the user-specified distribution for the tour category involved.

e. Upon completion of these operations, control is returned to the Simulator which calls the Attrition Simulator to proceed with the maturation of of this updated status record.

E. ATTRITION SIMULATOR

1. Purpose

The function of this module is twofold: (1) to execute the attritions for the current month which had been selected in the previous pass, and (2) to screen the records for attrition during the next month of simulation (or, pass).

2. Input Description

a. One personnel record.

b. CONUS excess counts.

c. Permanent and dynamic simulation parameters.

3. Output Description

a. One personnel record with updated status information on:

— Loss flag

— Expiration of term of service date (ETS)

— First-termer flag.

b. Attrition counts.

4. Function Relationships

The Attrition Simulator looks ahead one month, screening all records for attrition during the next month, and accumulating an attrition count. This count is required by the Driver so it can maintain a running count of the inventory. Records selected for attrition in the current month bypass the attrition selection module as well as the Promotion Simulator and Allocator Screen and are immediately transferred to the Personnel File Processor to be written on the Loss File rather than the new Personnel Status File. For these "drop" records, counts are accumulated by type of loss for

use in the Report Generator. CONUS excess attritions are not selected one month in advance but must be dropped in the same month they are selected based upon computations performed by the Driver after it has obtained the inventory count for the end of the current month.

5. Summary of Operations

a. If the loss flag in the record is greater than two, the record is to be dropped. After incrementing the appropriate counter, control is transferred, via the Simulator, to the Personnel File Processor to write the record on the Loss File.

b. If the loss flag is not greater than two but greater than zero (indicating an ETS loss or an up-or-out loss), the month of ETS is checked to see whether it equals the current simulation month. If it is equal, the appropriate loss counter is incremented, and control is transferred, via the Simulator, to the Personnel File Processor to write the record on the Loss File. Otherwise, the loss does not take place this month and control is transferred to the Promotion Simulator.

c. If the loss flag equals zero (or blank), the record may still be subject to attrition this month as a result of the CONUS excess. If there is an excess, a random number is generated, based upon the inventory by grade versus the excess by grade (as computed by the Driver), to determine whether the record is to be lost or not. If it is, the appropriate entry (code 6) is made in the loss flag field and control is transferred to the Personnel File Processor to write the record on the Loss File. If the record is not to be lost in the current month, it enters the attrition selection module.

d. Each record surviving the above tests is processed by the attrition selection module to determine whether the record will be lost in the next month. The logic is in accordance with Chapter II, section D, 1. Exceptional attrition was determined for the initial inventory and for all new accessions in the Driver and if the EEAD in the record equals the next month, the loss flag is set accordingly and further attrition screening is bypassed. Otherwise, separate sections will determine whether the record will be attrited due to: (1) up-or-out policy, (2) non-reenlistment or retirement, (3) general early-out, or (4) tour early-out, in that order. If a record is selected for loss, the appropriate loss flag is set:

1 = up-or-out
2 = non-reenlistment
3 = exceptional attrition
4 = general early-out
5 = tour early-out.

Similarly, if a record up for reenlistment at ETS is determined to be retained, the ETS in the record is updated by generating an appropriate reenlistment term and adding this to the current ETS. Also, if a first-termer will be retained, the first-termer flag is reset.

e. Upon completion of the attrition selection module, control is returned to the Simulator which calls the Promotion Simulator to continue processing of the record.

F. PROMOTION SIMULATOR

1. Purpose

The function of this module is twofold: (1) to execute promotions by grade and skill level for the current month for those airmen selected on the previous pass, and (2) to screen all records for promotion during the next pass.

2. Input Description

a. Personnel Status Record

b. Permanent and Dynamic Simulation Parameters

c. Promotion Ceilings

d. WAPS Cut-off Scores

3. Output Description

a. Personnel status record with updated information on:

- grade and skill level
- date of rank
- WAPS score
- date of skill level
- ETS

b. Promotion counts

4. Functional Relationship

The Promotion Simulator looks ahead one month, screening all records for promotion during the next month. Records selected for promotion in the current month are promoted through entering the new grade and/or skill level in the personnel status record. Promotion Counters are accumulated for use by the Report Generator. The Promotion Simulator is dependent upon the Driver for determining promotion eligibility (via the WAPS cut-off scores) as well as the maximum numbers which may be promoted by grade so as to avoid over-promotion.

Upon completion of processing by the grade promotion and skill level promotion modules, control is returned to the Simulator which calls the Allocator Screen to continue processing of the record.

5. Summary of Operations

a. Grade Promotion Execution

This module checks to see whether the WAPS score carried in the record is larger than the cut-off score determined by the Driver. (Notice that the logic of the grade promotion selection module described below is such that every record with a WAPS score greater than zero is eligibile for promotion.) If it is greater than the cut-off score, the record is promoted to the next higher grade by entering the new grade in the record. Otherwise, the record is not promoted. In view of the possibility of over-promotion (see section II, D.2), a current count of the number promoted by grade is maintained -- a count which is necessary also for the Report Generator. As soon as the maximum number (as determined by the Driver) has been promoted this month, no more promotions will take place for that grade on this pass, even though additional records may have a WAPS score larger than the cut-off score. Notice that promotion may require a change in the current ETS carried in the airman's record.

b. Grade Promotion Selection

Each record, including those just promoted, is processed through the grade promotion selection module to determine whether it will be eligible for promotion in the next month (pass). The detailed logic of promotion eligibility has been described in section II.D.2. If the record is ineligible, the WAPS score is set to zero. Otherwise, the WAPS score (resulting from the current weights applied to the current WAPS factor scores carried in the record) is entered into the record.

c. Skill Promotion Execution

This module updates the skill level of each record that has been selected for skill level promotion in the current month. The logic of the skill promotion selection module (see below) is such that the date-of-skill level field (IDOS) either carries the month in which the current skill level was attained (IDOS less than or equal to simulation month) or carries the month in which the next higher skill level will be obtained (IDOS greater than or equal to the simulation month). The skill promotion execution module checks whether the IDOS equals the current simulation month. If it does, the record is promoted through entering the next higher, legal skill level into the record, replacing the current skill level. Also, the appropriate skill level promotion counter is incremented. If IDOS is not equal to the current month of simulation, the record is not promoted and keeps it present skill level.

d. Skill Promotion Selection

This module processes any record with an IDOS less than the current simulation month. It determines whether such record meets the minimum requirements for skill level promotion in accordance with the logic described in section II.D.2. If it is not eligible, control is returned to the Simulator which calls the Allocator Screen to continue processing this record. If the record is eligible for skill level promotion, a time interval is drawn randomly from a given distribution of the time between becoming eligible for and award of next higher skill level. This interval is added to the current month of simulation to obtain the month of next higher skill level which is entered in the IDOS field. Upon completion of this module control is returned via the simulator to the Allocator Screen to continue processing the record.

G. ALLOCATOR SCREEN

1. Purpose

The function of this module is to determine which airmen are eligible to move and which are not. All records are categorized in terms of their assignment eligibility characteristics and defined accordingly through so-called row numbers which are entered into the records.

2. Input Description

a. Personnel status record

b. Permanent and dynamic simulation parameters

3. Output Description

a. Personnel status record with updated information on:

- expiration of term of service date (ETS)
- tour completion date (TCD)
- row number

b. Row counts

c. Vectors of row numbers

4. Functional Relationship

The Allocator Screen prepares essential information for the Allocator in an organized fashion. The row counts provide the row quotas in the allocation problem whereas the row numbers uniquely specify the assignment eligibilities. The vectors of row numbers maintained in central memory will also be used on the next data pass in the Allocation Posting Module to retrieve the new assignment of each reassigned airman.

5. Summary of Operations

a. In accordance with the logic described in section 2.D.3, a determination is made as to whether the airman is eligible (available) for transfer or not,

based upon the information contained in his record and the simulation parameters pertaining to the current month. Normally, availability for transfer is determined by the airman's TCD: if his TCD equals the current simulation month he is available for transfer. Four exceptions occur:

(1) Unavailability due to maximum time to ETS. Airmen (first termers as well as career airmen) not in CONUS and with less time to ETS than the maximum specified for transfer ineligibility are ineligible for transfer at TCD if they will not reenlist. Thus, if the record belongs to this category, the reenlistment decision must be simulated at TCD (prior to ETS). This is done through the normal Monte Carlo procedure, utilizing the appropriate reenlistment rate. If the record will be lost at ETS, the airman is not available for transfer and has his current tour extended. The loss flag in his record is set to two for information to the Attrition Simulator, and the record is classified as unmoveable. If the record will be retained at ETS a new ETS is computed and entered into the record. As the airman is available for transfer at TCD, the record is tentatively classified as moveable, subject to the special ineligibility discussed below.

(2) Special Transfer Unavailability. A proportion of airmen in non-CONUS tours are ineligible for transfer at TCD due to special reasons which are exogeneous to the model. The determination is made in a Monte Carlo fashion, given the proportion of airmen ineligible for transfer for such exceptional reasons.

(3) Unavailability due to minimum time to ETS. First term airmen (first termers only!) must have at least a certain minimum time to ETS in order to be eligible for a non-CONUS tour. For the category of first term airmen with less time to ETS than any one of the

minimums specified the model simulates the reenlistment decision at TCD prior to ETS in order to determine their availability/eligibility for transfer at TCD. This is done in the usual Monte Carlo fashion. If the record will be lost at ETS, the loss flag is set to two, and the record is classified as unmoveable (for the present time, subject to change in the input parameters). If the record will be retained at ETS, the airman's ETS is updated as well as the first termer flag, and the record is classified as moveable.

(4) CONUS, non-fixed airman. A proportion of the airmen in CONUS have a non-fixed tour length. Their TCD field carries the month their current tour began (DAUS) rather than a TCD (see Allocation Posting Module). The Allocator Screen recognizes such airmen by virtue of the TCD entry being less than the simulation month, whereas the TCD is always greater than or equal to the simulation month. The difference of simulation month minus DAUS is compared with the minimum time in CONUS specified for each non-CONUS tour to determine availability as well as assignment eligibility. Notice that CONUS, fixed airmen are always available for reassignment at TCD without exception.

b. Having determined whether the record is moveable or not, the assignment eligibility (tour categories to which the record may be reassigned) is determined based on the logic given in section II.D.3. Eligibility follows from the simulation parameters involving:

- permissible tour sequences (past, present and next)
- maximum number of tours per tour category
- minimum time since last tour in each category

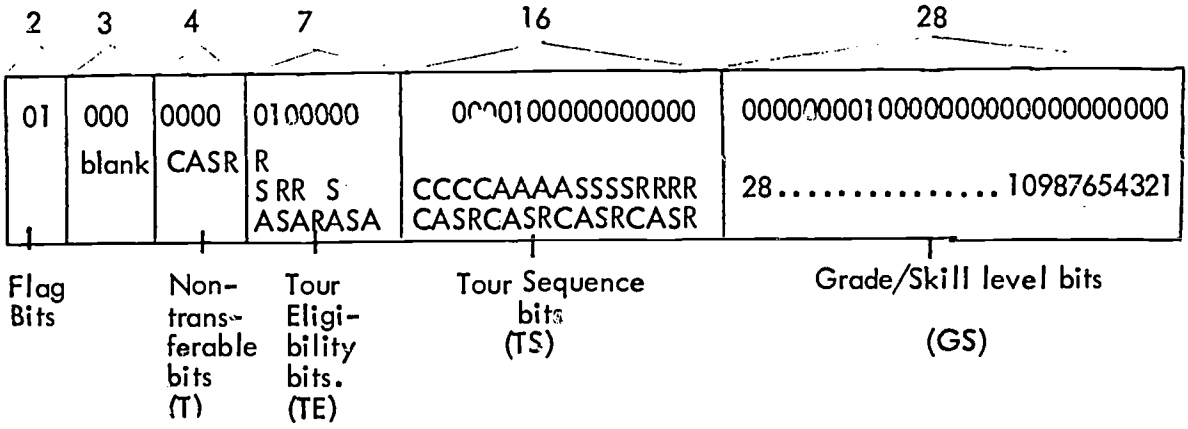
- minimum time in CONUS before each tour category

c. Having determined both availability for transfer and eligibility, a row number is computed for each airmen and entered into the record, and the row count for the category involved is incremented by one. (A category for non-moveable airmen is defined by grade/skill level/current tour, and for moveable airmen by grade/skill level/tour history/tour eligibility). The formulas used for generating the row numbers are given in Figure 6, Note 2. These row numbers promote an efficient method of uniquely specifying each airman's assignment eligibilities. Vectors of row numbers corresponding to the row counts are accumulated in central memory for use in the Allocator.

d. Upon completion, control is transferred via the Simulator to the Personnel File Processor to write the record on the Personnel Status File.

Figure 6

Row Bits Generated by Allocator Corresponding
To Row Numbers Generated by Allocator Screen



NOTES:

1. A specific row number is associated with airmen who have a specific grade/skill level combination, specific tour history, specific tour eligibility and same status (eligible for transfer or ineligible for transfer). Consequently, the above row bits generated by the Allocator for a particular row number contain at most one bit on (= 1) in each data field; the above bit entries provide one example. The function of the two flag bits is to provide proper linkage with the appropriate slack rows, depending on which QUOTFIND is executed: a technical complication not of interest to the model user.

2. Row numbers are computed by the Allocator Screen and entered in each status record as follows. Let:

   TE = Tour Eligibility (range: 0-7; "0" represents "CONUS only")

   TS = Tour Sequence = $(T_{past} - 1) \times 4 + T_{present}$ (range: 1-16)

   T = Tour (with: R = 1, S = 2, A = 3, C = 4)

   GS = Grade/Skill level combination (range: 1 - user specified maximum ≤ 28)

   GSN = Number of legal grade/skill level combinations ($8 \leq GSN \leq 28$)

   For airmen eligible for transfer with $TE \neq 0$:

   Row number = TE + (TS-1) x 7 + (GS-1)x 112

   For airmen eligible for transfer but with TE = 0 (i.e., CONUS only):

   Row number = 112 x GSN + TS + (GS -1) x 16

   For airmen not eligible for transfer:

   Row number = 128 x GSN + $(T_{present} - 1)$ * GSN + GS

H. PERSONNEL FILE PROCESSOR

1. Purpose

The sole function of this module is to write the updated record onto either the new Personnel Status File or the Loss File.

2. Input Description

Personnel Status.Record

3. Output Description

a. Personnel Status File

b. Loss File

4. Functional Relationship

The Personnel File Processor provides the interface between one data pass and the next month's data pass. It generates the personnel status file which will be input to the next month's simulation, after the Driver has added the records of new accessions. Therefore, two physical files are involved which are alternately used as input and output. In addition, this module dumps the records of airmen who are lost from the system on a cumulative loss file. After the final simulation month, the Personnel Status File is input to the Report Generator to be combined with the Loss File, converted from binary into external BCD, and output on an external tape for subsequent analysis by the model user.

5. Summary of Operations

a. The Personnel File Processor is entered directly from the Attrition Simulator with those records that are to be lost in the current simulation month. The type of loss is indicated by the Loss Flag. Each record so transmitted, is written onto the Loss File.

b. The normal entry for records remaining in the inventory is after the Allocator

Screen. Such records are written on the new Personnel Status File in the same order they are received in, i.e., new accessions are always at the back of the file in order of month of entry. The new file is tape 2 or 1 in alternate months.

c. Upon completion of dumping the record on either the Loss File or Personnel Status File, control is returned to the Simulator to process the next record (from tape 1 or 2 in alternate months) until all records have been matured one month. At that point, control is transferred via the Driver to the Allocator.

I. ALLOCATOR

1. Purpose

The Allocator is the most complex and important part of the entire model. The purpose of this module is to reassign simultaneously all airmen available for reassignment such that the following assignment objectives are optimized:

a. Maximize the fill of all assignment categories (tour/grade/skill level) where the quotas are based on the given authorized strengths by tour/grade/skill level minus the on-board airmen not eligible to move.

b. In the event that not all quotas can be filled (either due to a shortage of airmen or to their limited assignment eligibilities, or both), maximally accommodate the user-specified shortage distribution policies. These policies may include absolute fill priorities as well as relative sharing coefficients for assignment categories within the same fill priority.

c. Maximize the number of assignments involving the most desirable tour sequences. If assignments involving less desirable tour sequences are necessary to obtain the optimal solution on the first two objectives, maximize the number of those involving the most acceptable tour sequences and minimize those involving the least desirable tour sequences.

d. Maximize the number of assignments "on-grade and on-skill level." If grade and/or skill level substitutions are necessary to obtain the optimal solution to the first three objectives, maximize the number of most acceptable grade/skill level substitutions and minimize the number of least acceptable substitutions.

The final two objectives are, normally, interwoven by means of the user's specification of levels of fit.

h. The assignment solution outcome is stored in summary form for reporting purposes by the Report Generator in the form of "vectors of new assignments." For each row type, this vector contains the number of airmen assigned to each column. To retrieve the individual assignments from these new assignments vectors, it is possible to use the vector of row numbers which contains for each row number a pointer to the appropriate location in the corresponding vector of new assignments.

i. Upon completion, control is returned to the Driver to call the Report Generator for outputting the CAROM reports.

J. REPORT GENERATOR

1. Purpose

The purpose of this module is to produce all printed reports and data files output by the model. One segment produces the monthly summary reports, another segment produces the optional reports for the user-specified periods whereas a third segment in the final simulation month converts and reformats the loss file and personnel status file for further processing off-line, if so desired.

2. Input Description

a. Each month:

(1) Permanent and dynamic simulation parameters.

(2) Accession counts

(3) Attrition counts by type of loss

(4) Promotion counts by grade and skill level

(5) Allocation solution outcome (new assignments vector).

b. Additionally, in final month only:

(1) Personnel Status File, and

(2) Loss File

3. Output Description

a. Monthly Summary Report

b. Optionally, the Manning Level Report and/or Assignment, Loss and Promotion Report if requested for the current manth of simulation

c. In the final simulation month, the Personnel Status File and the Loss File.

provided to the Report Generator for reporting purposes while individual reassignments are communicated to the Allocation Posting Module for updating the personnel status records accordingly.

5. Summary of Operations

The assignment solution approach utilizes a set of complex, mathematical algorithms which are described in Appendix A. The more detailed description of the assignment logic in Chapter II, section D, 3, is briefly recapitulated below:

a. The initial column quotas are computed from (and are equal to) the given authorized strength figures pertaining to the next month of simulation.

b. The row counts, both for moveable and unmoveable airmen, were computed by the Allocator Screen. For purposes of the initial allocation (determination of compensatory shortages), these counts are collapsed into row quotas by grade/skill level/current tour.

c. For each row number in the vector of row numbers accumulated by the Allocator Screen, a sixty-bit word is generated, identifying the tour eligibilities of the airmen in the corresponding row (or category). This word is referred to as "row bits" and illustrated in Figure 6.

d. The column eligibility vectors prepared by the Control Card Processor are read in from file 6, specifying the allowable grade/skill level substitutions.

e. The first optimization stage is performed utilizing QUOTFIND to determine compensatory shortages (if any), as described in Chapter II, section D, 3. All airmen are eligible only for their current tour with grade/skill level substitutions permissible as specified. The result is a set of reduced quotas which account for any compensatory shortages which may be

necessary due to a dynamic change in the authorized strength.

f. The second application of QUOTFIND is designed to find the best possible allocation of aimen available for reassignment without addressing assignment desirability or "fit." The assignment eligibility of each row is found through ANDing the row bits and column eligibility bits. All moveable rows are made eligible for the CONUS overage category, but unmoveable rows are not. The result is a set of reduced quotas denoting the optimal fill of all assignment categories subject to the policy-dependent assignment eligibility matrix.

g. Within this solution, individual assignments are rearranged to improve the "fit," i.e., to optimize accommodation of the desirable assignment policies without affecting the reduced quotas. This is done through a successive surface optimization approach utilizing the OPTIMIZE algorithm. Assignment desirability vectors prepared by the Control Card Processor are read in from file 6 and ANDed with the row bits to determine the eligibility matrix for each level of desirability, starting with the most desirable level. For each level, an application of OPTIMIZE results in the identification of the "optimal surface" at this level, i.e., all possible assignment solutions which have in common a maximum number of assignments at the current desirability level. Each optimization is constrained by the previous one such that the "surface" becomes continuously smaller until possibly (but not necessarily) a unique assignment solution has been reached after which no more optimizations can be performed unless at the expense of higher-ordered objectives. CAROM allows a total of thirty-five successive optimizations.

4. Function Relationships

The Report Generator interfaces with all other modules of the system (except the Control Card Processor) through the Driver and has direct access to the results obtained in these modules: accession counts and CONUS excess counts from the Driver, attrition count from the Attrition Simulator, promotion counts from the Promotion Simulator and allocation summary results from the Allocator.

5. Summary of Operations

a. The monthly summary report is produced on the back of the same file which contains the control card listing and error diagnostics produced by the Control Card Processor as well as the error diagnostics produced by the Driver (file 8).

b. The detailed reports are produced on a separate file, file 4.

c. At the end of the simulation, it reads the current personnel status file (file 1 or 2) and the cumulative loss file (file 3) and puts out both files on tape 7, coded in external BCD and reformatted to facilitate further off-line processing of these data, if the user so desires.

IV. USER INSTRUCTIONS

This chapter provides the basic information for the model user to intelligently utilize CAROM for the analytical purposes discussed in Chapter II. The text is divided into two major parts, one specifying the model input and the other describing the model output. Through a careful study of this material, the user will be able to understand what input data are necessary to use the model, how this data must be prepared and submitted for model execution, how to interpret the simulation results and to what extent the input parameters may affect the evaluation criteria provided by the model output. Further instructions on the actual computer operation and execution of the model are provided in the next chapter as operator instructions, including the computer operating system control cards required to execute the model on a particular computer system.

A. SPECIFICATION OF MODEL INPUT

Data input requirements may be divided into two categories:

- Personnel data: to provide all simulation relevant information on each individual airman in the initial inventory as well as on future accessions.
- Control cards: to provide all parameters governing the simulation process, including those of a permanent nature (i.e., valid throughout the simulation run) as well as dynamic parameters (i.e., variable during the simulation run).

The following sections of this chapter provide a detailed specification of the content and use of the personnel data records and the control cards. (Record and card format specifications are included in Exhibits 1 through 26.) Each section is organized as follows:

— purpose and use

— limitations

— format and content

— relationship to output.

Special instructions regarding input media, sequencing, etc., are provided where necessary.

1. Personnel Records

Purpose and use

Personnel records specify all simulation relevant historical and current information required for each airman entering the system. The personnel records are used to both initiate the system and to feed the system new accessions during the simulation. The records are in fixed format as specified below (see also Exhibit 1).

Input media

Personnel Data Records are to be stored on a BCD tape or on disk in a format analogous to BCD tape. Personnel Data Records are subject to the following limitations:

a. Physical characteristics

(1) Physical record length: variable, 3 to 5120 characters.

(2) Blocking factor: variable, up to 100 logical records. Mixed blocking factors may be used (e.g., last physical record does not require padding).

(3) Recording mode: 7 track, even parity, external BCD (for character codes, see Exhibit 37).

(4) Density: 556 BPI (recommended) or 800 BPI.

(5) No header or trailer records are necessary; however, a double end of file mark (tape mark) signifies end of information (i.e., no more reels, no more data). If a multi-reel file is used as input, the last physical record

on a reel must cross the end of reel reflective mark. Records beyond the end of reel reflective mark are ignored.

b. Logical characteristics

(1) Logical records are fixed field and completely defined by the Format Specification (Exhibit 1).

(2) Logical records must be sorted by date of entry into the system. Different dates of entry must be separated by an end of file mark. The first file on the tape must be the initial inventory at the start of the simulation. Each successive file will be assumed to contain the following month's accessions (i.e., file 2 contains the first month's accessions, file 3 contains the second month's accessions, etc.) Physical records may be padded with all blank or all zero logical records if desired.

Format and content

Each personnel data record contains the following information:

— month of first enlistment

— Expiration of Term of Service (ETS) month

— grade and skill level

— date of rank and number of months in skill level

— current tour category

— Tour Completion Date (TCD)

— assignment history: the number of previous assignments and the most recent tour completion dates in each of the four tour categories

— WAPS factors: Specialty Knowledge Test (SKT), Promotion Fitness Examination (PFE), Airman Proficiency Rating (APR), Decorations Score, and two as-yet-unspecified factors.

All date information is in terms of simulation months relative to time 0, the month in which the simulation is started. The precise record format is provided by

Format Specification (Exhibit 1).

Both the initial inventory and new accessions use the same record format. However, for new accessions some of the above data may be inapplicable and the corresponding data fields may be left blank. For example, new accessions, normally, do not have assignment history data, unless they are prior service entries or lateral transfers from other career areas. Notice that the month of entry into the system for new accessions (from the entry-level training pipeline) is determined implicitly by the record sequence on the Personnel Data File. Consequently, the model user must take care in preparing the data such that the date information in the personnel records is consistent with the sequence of the records on the file. The system is programmed to ignore records with the following types of inconsistencies:

- ETS before date of entry
- date of entry before date of first enlistment
- date of rank before date of entry
- months in skill level larger than date of entry minus date of enlistment.

Such records are not processed by the model but included in the error messages generated by the Driver.

Sequencing

Personnel records are ordered, implicitly, by date of entry. The first batch of records (until the first end-of-file mark) represents the initial inventory, while every next batch of records (until the first subsequent end-of-file mark) represents the trained entries into the system during the corresponding month of simulation, starting with the first month.

Relationship to Output

The quantity and individual characteristics of the personnel records input to the model directly affect the model output. The simulation results contained in the monthly summary report and the two optional, detailed reports are dependent on the volume and characteristics of the personnel records. In addition, each record input to the model (and accepted by the model) is contained on either the loss file or the personnel status file output by the model with updated information at the end of the simulation run. The content of these output records is similar to the input records except for some additional data items (see Exhibit 32).

2. Control Cards

Description

The control cards define the parameter values for a particular CAROM run. The simulation parameters may be divided into two categories:

- Permanent parameters which remain valid or constant throughout the entire simulation run. These parameters are defined by card types 1 through 7.
- Dynamic parameters which may be altered for each and any simulation month if the user so desires. These parameters are defined by card types 8 through 25.

Input Media

All control cards consist of standard 80-column keypunch cards.

Format and content

The formats of all control cards are specified by Exhibits 2 through 26. The detailed content descriptions are provided for each card type separately below. All cards have the following data in common:

Card columns 1-3: Simulation month (right-justified) at which the data specified are in effect.

Card columns 5-6: Card type identification

A few general instructions pertaining to all control cards follows, supplementing the detailed comments for each separate card type.

All date information is in terms of simulation months relative to the start of the simulation in period "000", i.e., a date is always an integer between 0 and 360. Proportions must be specified as decimal fractions including the decimal, e.g., 1% is specified as ".01". All data items must be entered in the appropriate field.

All card types must be supplied as specified. If any information is missing at time 0, the model will abort with appropriate error diagnostics. After time 0 only those cards reflecting changes in specific dynamic parameters are necessary whereas the permanent parameters may not be changed. Such "change" cards may be left incomplete, i.e., only those fields which correspond to the particular parameter(s) the user wants to alter have to be punched. Fields left blank in such "change" cards imply that the corresponding parameters retain their last previous values. The only exceptions to this rule occur for card types 13, 14, 15, 19, 20 and 24. These cards establish distributions which must be reestablished completely every time a change is made in one of the values on these cards.

Sequencing

All control cards must be submitted in order of simulation month and by card type. Card types "01" through "07" (permanent data) must only be input with an effective date of "000" in columns 1-3. All other cards must also be input with an effective date of "000" followed by any "change" cards ordered by effective date, and within effective date by card type.

Relationship to output

See individual card type format and content descriptions below.

a. Card type 01 — Run Parameter Card

Purpose and use

The purpose of this card is to define general parameters which affect the simulation run and the model output.

Format and content

The format is specified by Exhibit 2. This card contains the following data:

(1) Type of run: Skill level only, grade only, or both skill level and grade.

(2) Report heading: The run identification and date to be printed at the top of each report output by the model.

(3) Length of simulation: The number of months the simulation run must proceed or, in other words, the final simulation month. The length of simulation is limited to 360 months. If it is specified as zero, no simulation run is made and the model will terminate after processing all control cards and performing the initial allocation.

(4) Schedule for optional reports: If optional reports are desired in addition to the Monthly Summary Reports, it is necessary to specify the first simulation month for which an optional report is requested as well as the interval (number of months) between successive optional reports. The

maximum amount of report output is produced by specifying month "1" as the first month for the reports and the interval as "1" month.

(5) Report selection: It is possible to select which of the optional reports are to be produced on the given schedule. Either the Manning Level Report (by grade and/or skill level) or the Assignment, Loss and Promotion Report (by grade and/or skill level), or both may be selected. The type of run determines which reports (by grade and/or skill level) are available.

(6) Maximum field length: This is computer jargon for the amount of memory required by and allocated to the execution of the model. This is a critical item of information as an insufficient field length will cause untimely termination of the run with the proper diagnostic message. The field length is also specified in the JOB card in the SCOPE control deck prepared by the Operator (see Chapter V). That field length determines the cost of the run, whereas the field length specified in card type 1 determines the amount of memory reserved for the run. It is, therefore, to the user's advantage to insure that the field length equals the field length specified in the SCOPE control card and that the field length is adequate for the run. The maximum field length possible on the CDC 6600 computer system is about 300K, whereas the minimum field length required for CAROM is about 110K. An estimate of the field length request for any particular run is provided by the following formula:

$$34800 + 278 \cdot NGS + C_1 \left[4 \cdot NGS + \text{Min } 3584, \text{Men}\right] + \text{Max}\left[0, \text{Min } (12000, \text{Men} - 3000)\right]$$

where NGS is number of legal grade/skill levels, and $C_1 = 2$ if NGS is 13 or less, or 3 if NGS is 14 or more.

Notice that the field length must be converted to octal for use in CAROM.

b. Card type 02 — Legal Skills and Grade/Skill Combinations Card

Purpose and use

This card defines the skill levels recognized by the model as well as the legal grade/skill level combinations.

Format and content

The format is specified by Exhibit 3. This card contains the following data:

(1) List of legal skill levels: A listing of all skill levels to be recognized by the model. Each skill level must be identified by an integer between 2 and 9, and a maximum of eight different levels may be specified. The levels may be specified in random order as the model will sort them in ascending order, with the lowest integer denoting the lowest level.

(2) List of legal grade/skill level combinations: For each grade, the lowest and highest skill level must be specified. The resulting legal grade/skill level combinations establish the assignment categories within each tour category, while the eight grade levels (with E1/E2 combined) are built into the model. A maximum of 28 grade/skill level combinations may be defined; for example, three skill levels are possible for each grade and four grades may have an additional, fourth skill level. It is essential that there be an overlap between the skill levels defined for consecutive grades so as to allow legal promotions within the framework of grade/skill combinations.

Relationship to output

As this card defines the level of discrimination by skill level, it also determines the level of discrimination in the CAROM reports. The specification of legal grade/skill level combinations may affect promotion eligibility and, thereby, the number of promotions in a given month, depending on the other

promotion-relevant parameters. The total number of legal grade/skill level combinations defined strongly affects the size of the assignment problems to be solved in the Allocator and, thereby, the computer cost of the run.

c. Card type 03 — Tour Sequence Desirability Card

Purpose and use

This card type defines the permissible tour sequences (past, present and next tour category) as well as the relative desirability of each specific tour sequence. The model recognizes four different tour categories, Remote (R), Special (S), Accompanied overseas (A), and CONUS (C). Personnel policies establish which tour sequences are not permissible as well as which sequence is more desirable than another from an individual career progression point of view or from the Air Force point of view such as equitability. Ultimately, the model attempts to reassign airmen available for reassignment in such a way that the number of assignments involving most desirable tour sequences are maximized, while assignments involving least desirable or most undesirable tour sequences are minimized. Actually, this card type is used in conjunction with card type 4 to define the "levels of fit" on card type 5. It is these "levels of fit" which are optimized by the model in reassigning airmen.

Format and content

The format is specified by Exhibit 4. One card of this card type must be submitted for each of the four tour categories. Each of these cards contains the following data:

(1) Tour identification: The next tour in the tour sequence; for each of the four tour categories, one card is submitted.

(2) List of permissible tour histories (past, present tour) in order of desirability for the next tour category specified. Because the tour histories have been

pre-coded for this card type, impermissible tour histories are identified by leaving the corresponding data field blank. For the same reason, the relative desirability of each tour sequence is specified by means of an alpha character between A and P in alphabetic order. The A denotes the most desirable tour sequence while the last symbol used (a P if all tour sequences are permissible) denotes the most undesirable tour sequence.

Relationship to output

The tour sequence desirability affects the assignment solution outcome because it is one of the assignment objectives optimized by the model. It does not affect the number of airmen assigned to or from each tour category nor the manning levels except insofar as certain tour sequences have not been specified because they are impermissible. Impermissible tour sequences constrain the assignment eligibility and, therefore, may reduce the fill of billets. The relative desirability may affect the proportion of spaces filled from grade or skill level above or below (as reported in the Monthly Summary Report) depending upon the specification of the levels of fit (card type 5) where the tour sequence desirabilities are interleaved with the grade/skill level substitution desirabilities. The tour sequence desirability does affect, however, the individual assignments made in the model. These assignments, or at least the most recent ones, can be retrieved from the records on the Personnel Status File and Loss File output by the model.

d. Card Type 04 — Grade/Skill Level Substitution Card

Purpose and use

This card type defines the permissible grade and skill level substitutions as well as the relative desirability of each specific substitution as established by personnel policies. Different substitution policies may be specified for each tour category or, alternatively, one policy may be applied to all four tour categories. The model assumes that on-grade and on-skill level assignments are the most desirable. The specified substitutions and their

relative desirability are used in the construction of the "levels of fit" on card type 5, in conjunction with the permissible tour sequences and their relative desirability (card type 3). The levels of fit are optimized in the model in reassigning the airmen available for reassignment. Thus, the model attempts to honor the grade/skill level substitution policy expressed on this card type if substitutions are necessary to achieve an optimal fill of billets. The model will always attempt to maximize the number of assignments on-grade and on-skill level and minimize the number of assignments involving the least desirable substitutions.

Format and content

The format is specified by Exhibit 5. One card of this card type must be submitted for each billet category defined for this run (tour/grade/skill level for run type "B," tour/grade for run type "G," or tour/skill level for run type "S") unless the same substitution policy applies for all tour categories. Each of these cards contains the following data:

(1) Billet category: tour, grade and skill level

(2) List of permissible substitutions (grade, skill level) in order of decreasing desirability. Because the desirability sequence has been pre-coded for this card type, the relative desirability of each grade/skill level substitution is specified by entering the grade and skill level in the appropriate card columns in desirability order. Similarly, impermissible substitutions are specified by omissions. If no substitutions are allowed, all substitution fields are left blank.

Relationship to output

The grade/skill level substitution desirability affects the assignment solution outcome because it is one of the assignment objectives optimized by the model. It does not affect the number of airmen assigned to or from

each tour category, nor the manning levels except insofar as certain substitutions have not been specified because they are impermissible. Impermissible substitutions constrain the assignment eligibility of airmen available for reassignment and, therefore, may affect the fill of billets or manning levels. The relative substitution desirability does affect the proportion of spaces filled from grade/skill level above or below as reported in the Monthly Summary Report. Of course, it affects who gets assigned to what billet in the model and these assignments, or at least the most recent ones, can be retrieved from the individual records on the Personnel Status File and Loss File output by the model.

e. Card type 05 — Level Definition Card

Purpose and use

This card type defines the levels of "fit" optimized by the model in the reassignment of airmen. For each assignment category (tour/grade/skill level), up to thirty-five levels may be defined specifying the relative desirability of assigning airmen with different tour histories and grade/skill level combinations to each assignment category. Level 1 represents the best level of fit, whereas each subsequent level represents a relaxation of the desired assignment characteristics down to the lowest level specified (level 35 or higher). The lowest level defines the minimum prerequisites (in terms of tour history, grade and skill level) for assignment eligibility to the assignment category involved. This method of policy specification has been chosen to allow the model user to interweave the assignment objectives of maximizing desirable tour sequences (card type 3) and of maximizing desirable grade/skill level substitutions (card type 4). The model rigorously honors the given levels of fit in the monthly reassignment of airmen. The assignment solution approach guarantees that the maximum number of assignments are made at level 1, subject only to the constraints resulting from the quota accommodation solution. If not all assignments can be made at level 1, the

model will attempt to maximize the number of assignments at level 2 without reducing the maximum number assigned at level 1, etc. For apparent reasons, this methodology is referred to as successive surface optimization.

Format and content

The format is specified by Exhibit 6. One card of this card type must be submitted for each billet category defined for this run -- a total of up to 112 cards if all grade/skill levels are used and if the fit policies are different for each tour category. Each of these cards contains the following data:

(1) Billet category: tour, grade and skill level

(2) List of the least desirable grade/skill substitutions and tour sequences in order of decreasing level of fit. Because the fit level sequence has been pre-coded for this card type, each level can be defined in terms of the letter designations from card types 03 and 04 associated with the least desirable grade/skill level substitutions and tour sequence, respectively, which qualify airmen at that level of fit for the billet category specified. In other words, each level is defined by two alpha characters: the first defines grade/skill substitutions (with the actual substitutions associated with this character defined on card type 04) while the second defines tour histories (with the actual tour histories associated with this character defined on card type 03). For example, assume that the following levels have been defined for a specific billet category:

	Grade/skill	Tour history
LEVEL 1	A	A
LEVEL 2	B	A
LEVEL 3	B	D

The implication of this definition is as follows. Fill those billets first with the maximum number of airmen possessing the same grade and skill level and the most desirable tour history. Next desirable are airmen with the first or second most desirable grade/skill level combination and the most desirable tour sequence. Thirdly desirable are airmen with the first or second most desirable grade/skill level combination and any of the four most desirable tour sequences.

A more detailed example may be useful to illustrate the flexibility of the model. This example is given in Figure 7 and is not necessarily intended to be realistic. It shows the different ways in which grade/skill level substitutions and tour sequences may be combined in defining levels of fit, depending on the relative weight of each factor.

Relationship to output

This has been discussed under the component parameters, card types 3 and 4.

Figure 7: EXAMPLE OF FIT LEVEL SPECIFICATION

Policy Specification on Card Types 3 and 4														
Billet category		Desirability Sequence A	B	C	D	E	F	G	H	I	J	K	L	Comments
Grade/skill level	E7/S6	7/6	7/4	7/8	6/6	6/8	8/6	---	---	---	---	---	---	Legal skill levels: 2, 4, 6, and 8. Entries are grade/skill level.
Tour category	R	CC	AC	CA	SC	CS	AA	SA	SS	AS	RC	RA	RS	Entries are previous tour, current tour, with the next tour identified in the first column. The following four sequences are impermissible: RR, SSS and AAA.
	S	CC	AC	RC	SC	AA	CA	RA	SA	CR	AR	SR	CS AS CA	
	A	CC	SC	RC	AC	SS	CS	RS	AS	CR	SR	AR	SA RA	
	C	SR	AR	CR	SS RS	RA	RC	AS	SA AA	CS CA	SC	AC	CC	

Policy Specification on Card Type 5 with 30 Levels of Fit						
	REMOTE TOUR: "Tour Sequence Critical"		SPECIAL/ACC. TOUR: "Grade/Skill Level Critical"		CONUS TOUR: "Tour history and grade/skill level Equally Unimportant"	
Level	Grade/Skill	Tour History	Grade/Skill	Tour History	Grade/Skill	Tour History
1	A	A	A	B	A	A
2	C	A	A	D	B	B
3	E	A	A	F	C	C
4	F	A	A	H	D	D
5	A	B	A	L	E	E
6	C	B	B	B	F	F
7	E	B	B	D	F	G
8	F	B	B	F	F	H
9	C	C	B	H	F	I
10	E	C	B	L	F	J
11	F	C	C	B	F	K
12	C	D	C	D	F	L
13	E	D	C	F		
14	F	D	C	H		
15	C	E	C	L		
16	E	E	D	B		
17	F	E	D	D		
18	C	F	D	F		
19	E	F	D	H		
20	F	F	D	L		
21	C	G	E	B		
22	E	G	E	D		
23	F	G	E	F		
24	C	H	E	H		
25	E	H	E	L		
26	F	H	F	B		
27	F	I	F	D		
28	F	J	F	F		
29	F	K	F	H		
30	F	L	F	L		

f. Card type 06 — Sharing Policy and Priority Level Card

Purpose and use

The purpose of this card type is to define the parameters governing the distribution of resources in the event that not all vacant billets can be filled. These parameters are of two kinds, priority levels and sharing coefficients. Billets with a high priority level will always be maximally filled at the expense of lower priority billets, even if it would reduce the fill of those lower priority billets to zero (which, actually, does not happen immediately in the model because airmen who have not completed their tour remain in their billets, thus providing a positive fill of the billet category even if no assignments are made to that billet category in a given month). On the other hand, if the billet categories within the same priority level cannot all be filled, the shortage is shared among these same-priority billets in accordance with the sharing coefficients specified for each billet category.

Once the distribution policy has been specified (a policy which must remain constant throughout the run), the model will optimally distribute airmen available for reassignment in accordance with that policy.

Format and content

The format is specified by Exhibit 7. Notice that two different formats are specified: one format must be used if the run recognizes skill levels only or grades only, but not both, whereas the other format must be used if both grades and skill levels are present in accordance with the run type specified on card type 1. In the first situation, one card of this type must be submitted for each tour. In the second circumstance, one card of this type must be submitted for each grade/skill level combination. Each card

contains the following data:

(1) List of billet categories: identified differently on the two formats depending on run type.

(2) List of corresponding sharing coefficients.

(3) List of corresponding priority levels.

Each billet category must have a (positive) priority level (an integer between 1 and 32) and sharing coefficient (a decimal fraction larger than zero and less than one thousand). Many or all billet categories may have the same priority level. A typical policy would be to specify different priorities for each tour category, with all billet categories within the same tour category assigned the same priority level. The specification of sharing coefficients may be more complex. In general terms, if all billet categories with the same priority level have identical sharing coefficients, the shortage of airmen (if any) will be distributed "fairly" across these billet categories so that they will tend to receive an identical fill (manning level). Unequal sharing coefficients would cause an "unfair" distribution, with billets carrying the highest sharing coefficients receiving the largest share. The format specification includes instructions how the model user may compute sharing coefficients from a hypothetical distribution of airmen representing his policy. Further details may be found in Chapter II, section D, 3, and in Appendix A.

Relationship to output

Because the distribution policy is the first objective optimized by the model in the reassignment of airmen, out-ranking the optimization of levels of fit, the distribution policy strongly affects the assignment solution outcome. In the Monthly Summary Report, the "per cent of total spaces" filled is

directly affected and so are all entries in the Manning Level Report and the assignments reported in the Assignment, Loss and Promotion Report.

g. Card type 07 — WAPS Updating Data Card

Purpose and use

The purpose of this card is to define the parameters governing the updating of some of the Weighted Airman Promotion System (WAPS) factors. The WAPS concept accounts for the following factors in determining the promotability of one airman versus another:

- Time-in-grade and time-in-service
- Three test scores: Specialty Knowledge Test (SKT), Promotion Fitness Examination (PFE) and Airman Proficiency Rating (APR), whereas the model is designed to accommodate two additional tests in the future if the model user desires.
- Decorations score.

These factors and the weights applied to them determine an airman's WAPS score which, in turn, ranks airmen in order of promotability. To provide a realistic simulation of the promotion of personnel, it was deemed inadequate to update only an airman's time in grade and service, two basic airman characteristics which are continuously updated in the course of the simulation. The other WAPS factors must be updated also, and this card specifies the necessary parameters used in the model.

Format and content

The format is specified by Exhibit 8. Only one card must be submitted which contains the following data:

(1) Updating interval: the interval between successive updates of the test scores, assuming that all input records had been updated by the user as of month 0. In other words, if the interval is 12 (months), all records in the model have their test scores updated in month 12, 24, etc., including records which entered the model, say, in month 11.

(2) Standard deviations of the test scores: the standard deviations in conjunction with the airman's original test scores (at entry) determine the test score distributions from which an airman's updated test score is sampled (see Chapter II, section D, 2).

(3) Decorations score: the decorations score of each airman is updated every time he completes a tour. The maximum score specified here simply puts a ceiling on the decorations score any airman may accummulate.

Relationship to output

The WAPS factors affect an individual airman's chance of promotion but do not affect the number of promotions in a given month. Consequently, these update parameters do not influence any data item in the CAROM reports. Because they may affect an individual's career, any impact is found in the airman records on the Personnel Status File and the Loss File output by the model: airmen entering the model in the same month and still on-board in the final simulation month but in different grade levels must have had significant differences in their WAPS scores at some time during the simulation. It is, however, difficult to detect whether the update parameters have been contributing factors or not. Overall, it is believed that the updating of test scores has a negligible effect on the simulation results and only contributes to increasing the run time of the model. The critical

observer may view the updating of test scores (and decorations as well) as an unwarranted level of simulation detail, considering the purposes of the model. Any effect the test scores may have is primarily determined by each airman's initial test scores as specified by the model user in the personnel records input to the model. The user can by-pass the score updating feature by specifying an updating interval larger than the length of simulation.

h. Card type 08 — Model Parameter and Eligibility Card

Purpose and use

The purpose of this card type is to define a collection of miscellaneous parameters which affect an airman's availability and eligibility for reassignment as well as the total authorized strength and the rate of exceptional attrition, including the month in which the parameter values become effective. Different parameter values may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 9. One card of this card type must be submitted with one or more change cards if the parameter values must be changed during the simulation. Each card contains the following data (although any change cards need only specify those parameter values which must be changed from the last previous values):

(1) Effective simulation month: month in which values specified become in effect.

(2) Authorized strength: the total authorized strength for the career area being simulated; i.e., the sum of all grade/skill level billets in all four tour categories.

(3) Maximum CONUS overage: the maximum allowable overage in CONUS over and above the authorized strength expressed as a proportion of the authorized strength. The authorized strength plus the allowable excess determine the maximum number of airmen in the system at any point in time. If the personnel inventory in the model tends to accumulate beyond this ceiling, airmen are attrited under special policies to keep the inventory under this ceiling.

(4) Exceptional attrition rate: One flat rate applies to the entire inventory. A Monte Carlo procedure determines upon entry into the model whether an airman will be lost or not, and if so, in what month. The resulting exceptional attrition date (if any) is entered into his record and the airman is attrited in the appropriate month.

(5) Minimum time in CONUS before non-CONUS tour: these parameters specify the minimum number of months in CONUS for an airmen to be eligible for reassignment to each of the three non-CONUS tour categories.

(6) Maximum CONUS tour length: for airmen not on a "fixed" but on a "non-fixed" CONUS tour, this parameter specifies how long they may remain on their current tour. Airmen not reassigned to a non-CONUS tour before reaching the maximum CONUS tour length are reassigned in CONUS.

(7) Proportion of returnees in stabilized positions: this parameter specifies the proportion of all airmen reassigned to CONUS in a given month

(either from a non-CONUS tour or from a CONUS tour) who receive a fixed CONUS tour length. If this proportion is 1, all CONUS assignees receive a fixed CONUS tour length and will become available for reassignment at the tour completion date (TCD). If this proportion is 0, all CONUS assignees are subject to the minimum and maximum times in CONUS specified above for reassignment availability and eligibility. Instead of a TCD, their date arrived in CONUS (DAUS) governs reassignment availability.

Relationship to output

All of these parameters have a strong effect on the CAROM output. The total authorized strength is reported in the Monthly Summary Report and, via the percentage by billet category specified in card type 19, determines the authorized billets by tour category (Monthly Summary Report) and by tour/grade and/or skill level (Manning Level Report). As the authorized strength determines the number of billets (column quotas) in the allocation, it directly influences the reassignment of airmen and, particularly, the overages and shortages reported in the above two reports. Dynamic changes in the authorized strength during the simulation may influence the number of airmen to be lost due to excess beyond the allowable overage. Such losses are included in the losses reported in the Monthly Summary Report and specified, separately, in the Assignment, Loss and Promotion Report.

The maximum CONUS overage specification similarly affects the losses due to CONUS excess. The smaller the overage allowed, the more airmen may have to be lost to keep the inventory under the ceiling allowed.

The exceptional attrition rate determines, of course, the exceptional attritions in the model; these losses are included in the losses reported in the Monthly Summary Report and reported separately in the Assignment, Loss and

Promotion Report. As these exceptional attrition losses, in conjunction with other types of losses as well as the new accessions, determine the inventory, the exceptional attrition rate may indirectly affect the assignment solution outcome, i.e., the numbers of spaces filled in the Monthly Summary Report and the overages or shortages in the Manning Level Report. Also, exceptional attritions, to some extent, influence the number of promotions.

The minimum times in CONUS to be eligible for non-CONUS tours directly determine the assignment availability and eligibility of airmen to fill non-CONUS billets. If these conditions are overly constraining, a shortage in the non-CONUS tours may result and/or the quality of "fit" will deteriorate, i.e., the number of assignments involving undesirable grade/skill substitutions and tour sequences will steadily increase in an attempt to fill all non-CONUS billets until even at the most undesirable level of fit insufficient airmen are available for assignment so that shortages occur. These parameter specifications thus affect the fill and substitutions reported in the Monthly Summary Report as well as the Manning Level Report and the number of assignments to each non-CONUS billet category reported in the Assignment, Loss and Promotion Report.

The maximum CONUS tour length has an effect on the number of airmen available for reassignment, but this effect is difficult to determine a priori. In general, a short duration would result in repeated reassignments in CONUS as a result of which a proportion of such airmen would be repeatedly frozen in stabilized positions in CONUS during which they would be unavailable for reassignment even though they were accumulating time-in-CONUS beyond the minimum required for assignment eligibility to a non-CONUS tour. This

might possibly cause a shortage in non-CONUS billets or a decreasing quality of fit, although this effect would strongly depend on the proportion reassigned to stabilized ("fixed") CONUS positions. On the other hand, a long duration for the maximum CONUS tour length would keep airmen continuously available for reassignment as soon as they had accumulated the required minimum time in CONUS. This would, probably, improve the fill of non-CONUS billets, both quantitatively and qualitatively.

The proportion of CONUS assignees receiving a fixed tour length is an important parameter, the effect of which is strongly dependent on the duration of this fixed CONUS tour length (card type 20). If this proportion is large and the fixed tour length is long, the result will be a decrease in the number of airmen available for reassignment compared with the situation where the proportion is small. The net effect is then a reduction of the fill of non-CONUS billets as well as a decrease in the quality of fit of those airmen assigned to these billets.

i. Card type 09 — Minimum Time in Grade Card

Purpose and use

The purpose of this card is to define for each grade the time-in-grade prerequisite for promotion to the next higher grade. Different parameter values may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 10. One card of this card type must be submitted while one or more change cards may be included if the parameter values must be changed during the simulation run. This card contains the following data (although any change cards need only specify those particular

parameters which are to be changed from the last previous values):

(1) Effective simulation month: month in which values specified become effective.

(2) Minimum time in each grade required for promotion eligibility for the next higher grade.

Relationship to output

These parameters primarily affect the promotability of each individual airman, and as such do not directly influence the aggregate simulation results in the CAROM reports. However, to the extent that the minimum times in grade specified are overly constraining (i.e., exceptionally long), it is possible that the promotion flow stagnates as the minimum time in grade is a mandatory prerequisite for promotion. In that case, the top grade billets would tend to be underfilled depending on the permissible grade substitutions. These results would be evident in the Monthly Summary Report (number of promotions), the Manning Level Report (overages/shortages in billets as well as a high percentage of substitutions from grade below) and the Assignment, Loss and Promotion Report (numbers assigned to each billet category as well as the up-or-out losses) because stagnation in lower grades would lead to an increase in forced up-or-out losses depending upon the up-or-out policy (card type 18).

j. Card type 10 — Minimum Time in Skill Level Card

Purpose and use

The purpose of this card is to define for each legal skill level the time-in-skill level prerequisite for promotion to the next higher skill level. Different parameter values may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 11. One card of this card type must be submitted while one or more change cards may be included if the parameter values must be changed during the simulation run. This card contains the following data (notice that any change cards need only specify those particular parameters which are to be changed from the last previous values):

(1) Effective simulation month: month in which values specified go into effect.

(2) For each legal skill level (except the top level), the minimum time required for promotion to the next higher legal skill level. Obviously, the skill levels used here must conform to the list of legal skill levels defined previously (card type 2).

Relationship to output

These parameters primarily affect the promotability of each individual airman and, as such, do not directly influence the aggregate simulation results in the CAROM reports. However, if the required time-in-skill level for promotion is made exceptionally long, a stagnation in the skill level promotion flow may be the result depending, in part, on the time interval between attainment of eligibility for promotion to and award of the next higher skill level (see card type 13). The effects of such stagnation would be immediately evident from the simulation results in the CAROM reports: decreased fill of billets, a large percentage of billets filled from skill levels below and small numbers of skill level promotions (Monthly Summary Report), shortages in the higher skill levels with a large percentage filled from skill levels below (Manning Level Report) and less assignment moves for the higher skill levels (Assignment, Loss and Promotion Report). Skill level

promotions are linked, to some extent, to grade promotions as promotion to each grade requires as mandatory prerequisite a certain minimum skill level. Consequently, skill level promotion flow stagnation leads after a time lag to grade promotion stagnation. Those effects have been discussed under card type 9.

k. Card type 11 — Minimum Time in Service Card

Purpose and use

The purpose of this card is to define for each grade the minimum time-in-service prerequisite for promotion to that grade. Different parameter values may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 12. One card of this card type must be submitted, while one or more change cards may be included if the parameter values must be changed during the simulation run. This card contains the following data (notice that any change cards need only specify those particular parameters which are to be changed from the last previous values):

(1) Effective simulation month: month in which values specified become effective.

(2) Minimum time-in-service (months since first enlistment) for each grade (except the lowest one).

Relationship to output

These minimum time-in-service parameters primarily determine an individual airman's rate of advance up the career ladder. As such, they do not directly influence the aggregate simulation results reported in the

CAROM output. However, similarly to the minimum time in grade parameters, an overly restrictive policy may lead to stagnation of the grade promotion flow with the effects described under card type 9.

1. Card type 12 — WAPS Factor Weights Card

Purpose and use

The purpose of this card type is to define the weights for each of the Weighted Airman Promotion System (WAPS) factors in computing the WAPS score for each airman. The WAPS score determines the promotability of one airman vis-a-vis another in the same grade if they meet the mandatory prerequisites for promotion: minimum time in grade, minimum time in service and minimum skill level for next grade. The method of specification allows the model user to evaluate any conceivable promotion policy. Weights may be selectively set to zero so that, for example, the impact may be assessed of a policy which promotes by test performance only and ignores time in grade and service, if the user so desires. Different weights may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 13. One card of this card type must be submitted for each grade, while one or more change cards may be included for those parameter values which must be changed during the simulation run. Each card contains the following data (change cards need only specify the parameter values to be changed and their effective date):

(1) Effective simulation month: month in which values specified become effective.

(2) Grade of airman up for promotion.

(3) Eight weights (between 0 and 100), one for each WAPS factor.

Relationship to output

As the weighting factors solely determine an individual's promotability, these parameters do not affect the aggregate simulation results reported in the CAROM output. They do not affect the number of promotions, but only who is promoted. Any effects on the career advance of individual airmen may be retrieved through analysis of the airman records output on the Loss File and the Personnel Status File.

m. Card type 13 — Skill Level Promotion Distribution Card

Purpose and use

The purpose of this card type is to define the distribution of the time interval between the time that an airman first becomes eligible for the next higher skill level and the time of award of that skill level. Through these parameters and the minimum time in skill level on card type 10, the model user controls the rate of skill level promotion within the model. Moreover, through definition of the legal grade/skill level combinations (card type 2), each grade requires a certain minimum skill level. Therefore, these parameters also provide an indirect effect on the rate of grade promotion within the model. Different distributions may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 14. At least one card of this card type must be submitted for each legal skill level; the model user may submit two cards per skill level if he wants to specify a more detailed distribution (up to ten discrete time intervals) than possible with one card (up to five discrete time intervals). Any change cards included for the purpose of changing the distribution during the simulation run must specify the complete

distribution (and not only the parameters to be changed as allowed for most other card types). Each card contains the following data:

(1) Effective simulation month: month in which distribution specified becomes effective.

(2) Skill level.

(3) Five discrete time intervals, each with the associated probability. Notice that for computational reasons each probability or proportion must be greater than 0 (though it may be finitely close to 0) and less than or equal to 1. The proportions specified do not necessarily have to add up to 1.0: the model automatically normalizes each distribution specified in the input stream such that the normalized proportions add up exactly to 1.

Relationship to output

In conjunction with the parameters specified on card type 10, card type 13 determines the skill level promotion flow. If the intervals between eligibility for and award of the next higher skill level are excessively long, shortages may result in the higher skill levels and, ultimately, in the higher grade levels. The effects of this situation on the CAROM output will be similar to those described under card type 10.

n. Card type 14 — First Termer Reenlistment Distribution Card

Purpose and use

The purpose of this card is to define the terms of first reenlistment and the proportion of reenlistees per reenlistment term. Notice that the actual retention rates are specified on a different card type (see card type 17). The first termer reenlistment distribution is used in the model to determine the new ETS for each first term airman who reenlists. Different distributions

may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 15. At least one card of this card type must be submitted by the user; multiple cards may be submitted if the user wants to specify more than five different reenlistment terms. Any change cards included for the purpose of changing the reenlistment terms and/or the corresponding proportions during the simulation run must specify the complete distribution (rather than only those parameters to be changed as allowed for most other card types). Each card contains the following data:

(1) Effective simulation month: month in which distribution specified becomes effective.

(2) Five different reenlistment terms, each with the corresponding proportion of reenlistees. Notice that for computational reasons each proportion must be greater than 0 (though it may be finitely close to 0) and less than or equal to 1. The proportions specified do not necessarily have to add up to 1: the model automatically normalizes each distribution specified in the input stream such that the normalized proportions add up exactly to 1.

Relationship to output

The effect of the first termer reenlistment distribution on the CAROM output is difficult to indicate a priori. These parameters do not influence the number of first term reenlistees, but they do influence the future inventory. Longer first reenlistment terms tend to increase the inventory later on, assuming that the retention rates, on the average, decrease with time in service (card type 17). This effect is indirect and may be negligible. In any

case, the effect may be easily evaluated through making multiple CAROM runs with identical data except these parameters: any change in the actual strength in the Monthly Summary Report is caused by the difference in these parameters.

o. Card type 15 — Careerist Reenlistment Distribution Card

Purpose and use

The purpose of this card is to define the reenlistment terms of career airmen and the proportion of reenlistees per reenlistment term. Notice that the actual retention rates are specified on a different card type (see card type 17). The careerist reenlistment distribution is used in the model to determine the new ETS for each career airman who reenlists. It must be emphasized that these reenlistment terms apply only to careerists with less than 20 years in service. Airmen close to 20 years will always first receive an ETS corresponding to exactly 20 years of service (rather than beyond), after which the model assumes that they reenlist each time for only one year until voluntary retirement or mandatory retirement at 30 years of service. Different distributions may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 16. At least one card of this card type must be submitted by the user; multiple cards may be submitted if the user wants to specify more than five different reenlistment terms. Any change cards included for the purpose of changing the reenlistment terms and/or the corresponding proportions during the simulation run must specify the complete distribution (rather than only those parameters to be changed as allowed for most other card types). Each card contains the following data:

(1) Effective simulation month: month in which distribution specified becomes effective.

(2) Five different reenlistment terms, each with the corresponding proportion of reenlistees. Notice that for computational reasons each proportion must be greater than 0 (though it may be finitely close to 0) and less than or equal to 1. The proportions specified do not necessarily have to add up to 1: the model automatically normalizes each distribution specified in the input stream such that the normalized proportions add up exactly to 1.

Relationship to output

Any effect of these parameters on the aggregate simulation results reported in the CAROM output is similar to the possible effect described for the first termer reenlistment distribution (see card type 14).

p. Card type 16 — Minimum Promotion Obligation Card

Purpose and use

The purpose of this card is to define the minimum obligation upon promotion to each grade. This parameter is used within the model to adjust, if necessary, an airman's ETS when he is promoted: if his time to ETS is less than the minimum obligation incurred upon promotion, his ETS is moved back to meet the minimum obligation requirement. The only exception to this occurs when the minimum obligation would put an airman past thirty years of service; in that event the minimum obligation is waived and his ETS is set at the thirty years of service point. Different parameter values may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 17. One card of this card type must be submitted by the user, while one or more change cards may be included for those parameters which must be changed during the simulation. Each card contains the following data (change cards need only specify the parameters to be changed and their effective date):

(1) Effective simulation month: month in which parameters specified become effective.

(2) Obligation upon promotion to each grade (except grade E2/E1).

Relationship to output

These parameters affect the size of the inventory: promotion obligations tend to keep airmen (at least temporarily) in the service -- airmen who otherwise might have been lost due to nonretention. While this effect may be slight with respect to the category of less than twenty years in service, it may be expected to be more pronounced for the category eligible for early retirement (twenty to thirty years in service). Thus, the items influenced in the CAROM output include the actual strength and per cent of total spaces filled (Monthly Summary Report), the actual fills of billets (Manning Level Report) and the nonreenlistment losses (Assignment, Loss and Promotion Report).

q. Card type 17 — Retention Rate Card

Purpose and use

The purpose of this card type is to define the retention rates as a function of time-in-service. The given rates determine the retention process simulated by the model. Different parameters may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 18. Three cards of this card type must be submitted, while one or more change cards may be included for those parameters which must be changed during the simulation. Each card contains the following data (change cards need only specify the parameters to be changed and their effective date):

(1) Effective simulation month: month in which parameters specified become effective.

(2) Retention rate for each years-in-service category, with ten successive service times per card.

Relationship to output

The retention rates have a strong effect on the size of the inventory. Therefore, they affect the actual strength and billet fill reported in the Monthly Summary Report, the detailed grade/skill level billet fill reported in the Manning Level Report and the nonreenlistment losses reported in the Assignment, Loss and Promotion Report. Also, the retention rates influence the number of slots open for promotion and, thereby, the number of promotions.

r. Card type 18 — Up-or-Out Policy Card

Purpose and use

The purpose of this card is to define the parameters associated with an up-or-out policy, i.e., the maximum time in service allowed for each grade. Airmen reaching the maximum time specified for their grade and who are not promoted will not be retained at ETS. These losses are over and above the normal nonretention losses and are referred to as up-or-out losses. Different parameters may be specified in advance for different simulation periods.

Format and content

The format is specified by Exhibit 19. One card of this card type must be submitted while one or more change cards may be included for those parameters which the user wants to change during the simulation. This card contains the following data (change cards need only specify those parameters to be changed and their effective date):

(1) Effective simulation month: month in which parameters specified become effective.

(2) Maximum time in service for each grade (except E9).

Relationship to output

These parameters influence the airman inventory, particularly when other parameters tend to limit the promotion flow (see card types 9, 10, 11 and 13). Thus, the items in the CAROM output affected by these parameters are similar to those described for card types 16 and 17. In the Assignment, Loss and Promotion Report a separate line (for each tour category) specifies the up-or-out losses in each grade.

s. Card type 19 — Authorized Strength Card

Purpose and use

The purpose of this card type is to define the authorized billets by tour category and grade and/or skill level (depending upon the type of run). The authorized billets provide the assignment categories and their quotas for use by the Allocator in the reassignment of airmen. Different parameters may be specified in advance for different periods of the simulation.

Format and content

The format is specified by Exhibit 20. Two different card formats are prescribed depending on the type of run: (1) grade or skill level only, or

(2) grade and skill level combinations. For the first type of run, one card of this card type must be submitted for each tour category, while one or more change cards may be included for modifying the strength distribution during the simulation. Each card of the format contains the following data:

(1) Effective simulation month.

(2) Tour category identification.

(3) Proportion of billets in each grade or skill level in the tour category specified.

(4) Proportion of total authorized strength comprising the tour category specified.

For the second type of run, one card of this card type must be submitted for each tour/skill level combination, while one or more change cards may be included for modifying the strength distribution during the simulation. Each card for this format contains the following data:

(1) Effective simulation month.

(2) Tour category identification.

(3) Skill level.

(4) Proportion of billets in each grade for the tour/skill level combination specified.

(5) Proportion of total authorized strength represented by the tour/skill level combination.

For both card formats, it must be noticed that the proportions specified in each card ought to add up to 1.0 for each card, whereas the proportions of total authorized strength (one per card) ought to add up to 1.0 for all cards submitted. However, the system automatically normalizes the distributions in the input stream such that any input errors are compensated

for and the actual distributions used within the model meet this requirement. Notice also that, in contrast to the other distributions specified by the model user (e.g., card types 13, 14, 15, 20 and 24), one or more of the proportions specified may equal zero (but not all). As is the case for all input distributions, any change cards of this card type must specify the complete distribution.

Relationship to output

The authorized strengths specified (in conjunction with the total authorized strength on card type 8) appear in the CAROM reports, both in the Monthly Summary Report and the detailed Manning Level Report. The authorized strengths are, of course, one of the basic parameters of the model, defining the structure and size of the assignment problem or the environment within which the impact of other model parameters may be assessed. Changing the authorized strength distributions during the simulation period is a valid parameter for investigation, but makes the problem of interpreting the model results more complex than for stationary types of runs (i.e., with constant authorized strength and constant distributions). Because the authorized strengths or billets are a basic model parameter, they influence, indirectly, all of the model results documented by the CAROM reports.

t. Card type 20 — Tour Length Distribution Card

Purpose and use

The purpose of this card type is to define the tour duration in each tour category. The model user has a wide margin of flexibility in specifying these tour lengths, from nearly deterministic to completely random (i.e., uniformly distributed over a prespecified time interval) including any shape of discrete distribution in-between. These parameters are used within the model to determine a Tour Completion Date (TCD) for each airman upon

reassignment, thereby establishing the period during which he cannot be moved. (This applies to all airmen except for those assigned to CONUS non-fixed positions who do not receive a fixed tour length.) Different parameters may be specified in advance for different periods of the simulation. Of course, if the user changes the tour length distribution for one or more tour categories, as of a certain simulation month, there is a brief time interval during which not all airmen follow the new rules: TCD's once computed in the model are not modified to accommodate a new tour length distribution. Consequently, those airmen who have already a TCD based on the previous tour length distribution keep their TCD in spite of the new tour length distribution. But all airmen reassigned in that month or thereafter will follow the new tour length distribution.

Format and content

The format is specified by Exhibit 21. One card of this card type must be submitted for each tour category, while one or more change cards may be included to re-specify the distribution(s) during the simulation. Each card contains the following data:

(1) Effective simulation month.

(2) Airman category: first-termer or career airman.

(3) Tour category identification.

(4) Five different tour lengths and the corresponding proportions of airmen receiving that tour length.

The tour length distribution for a specific tour and airman category (first-termer/careerist) is thus limited to five discrete tour lengths. Notice that for computational reasons the proportions specified must all be greater than zero (but may be finitely close to zero). The proportions specified on each

card ought to add up to 1.0 for each card. However, the model automatically normalizes all distributions specified in the input stream such that the actual distribution used within the model satisfies this requirement if the user makes an input error.

Relationship to output

These parameters influence the number of airmen available for reassignment each month and, thereby, the number of assignments specified in the Monthly Summary Report and the Assignment, Loss and Promotion Report. Several indirect effects are present also. Depending upon the assignment eligibility conditions (card types 8 and 21), it may be expected that non-CONUS billets, normally, are more difficult to fill than CONUS billets. By specifying very long CONUS tours (in conjunction with a large proportion of "fixed" CONUS assignments on card type 8) with relatively short non-CONUS tours, it is possible to structure the rotation problem such that CONUS has an overage while non-CONUS billets cannot be filled. Vice-versa, long non-CONUS tours and short CONUS tours will virtually assure that all billets can be filled, assuming everything else being equal.

u. Card type 21 -- Assignment Eligibility Card

Purpose and use

The purpose of this card type is to define the parameters which determine the assignment eligibility of an airman for a particular tour category. In conjunction with the parameters specified in card type 8 and the permissible tour sequences specified in card type 3, these parameters uniquely establish the rotation policy to be used in the model in the reassignment of airmen. Different parameter values may be specified in advance for different periods of the simulation.

Format and content

The format is specified by Exhibit 22. One card of this card type must be submitted for each non-CONUS tour category, while one or more change cards may be included for parameter values to be changed during the simulation. Each card contains the following data (change cards need only specify those parameters to be changed and their effective dates):

(1) Effective simulation month.

(2) Tour category identification.

(3) Minimum time since last tour for each of the three non-CONUS tour categories in order to be eligible for the tour category specified.

(4) Maximum number of tours in the tour category specified, one figure for first-termers and another for career airmen.

(5) Minimum time to ETS for first-term airmen elsewhere to be eligible for the tour category specified.

(6) Maximum time to ETS for airmen in the tour category specified at TCD to be ineligible for transfer from this tour category; one figure for first-termers and another for careerists.

(7) Proportion of airmen in this tour category who are unavailable for transfer at TCD due to special reasons.

All of these parameters constrain availability or eligibility for reassignment. Notice that different parameter values may be specified for first-term airmen and career airmen. The minimum time to ETS for eligibility applies only to first-termers. A first-term airman available for reassignment is not necessarily constrained by this condition: the simulation of his retention is simply moved up from ETS to the (earlier) TCD and if he will be retained, the airman will be eligible in spite of this condition.

Relationship to output

These parameters determine the structure of the assignment eligibility matrix and, thereby, the assignment solution outcome. They affect the fill of billets reported in the CAROM output, as well as the numbers of assignments to each non-CONUS tour category.

v. Card type 22 — General Early-Out Policy Card

Purpose and use

The purpose of this card is to define the parameters associated with a general early-out policy for first-term airmen. Career airmen are not eligible for general early out, only for tour completion early out (see card type 23). The parameters specified are used in the model to force the appropriate number of first-termers early-out at tour completion if they are eligible. Different parameter values may be specified in advance for different periods of the simulation.

Format and content

The format is specified by Exhibit 23. Only one card of this card type must be submitted, while one or more change cards may be included to specify changes in the parameter values during the simulation and their effective dates. The content of this card is as follows:

(1) Effective simulation month.

(2) Maximum time to ETS for first termers to be eligible for early out at tour completion.

(3) Proportion of those eligible for early out who accept an early out. Different proportions may be specified for the four different tour categories.

Relationship to output

These parameters in conjunction with those specified on card type 23 determine the early outs selected in the model and reported in the Assignment, Loss and Promotion Report. Early-out losses are included under the column "losses from tour" in the Monthly Summary Report. Early-out losses, in turn, affect the actual strength and manning levels reported in the CAROM output and, thereby, the overages and shortages, as well as the promotion opportunity.

w. Card type 23 — Tour Completion Early-Out Card

Purpose and use

The purpose of this card type is to define the parameters associated with a tour completion early-out policy. Both first-term airmen and career airmen may be eligible for this early-out policy. The parameters specified are used in the model to early-out the appropriate numbers of first-term and career airmen at completion of a non-CONUS tour. The individuals are selected randomly from those eligible for early-out. Different parameters may be specified in advance for different periods of the simulation.

Format and content

The format is specified by Exhibit 24. One card of this card type must be submitted for each of the two airman categories, first-termers and careerists, while one or more change cards may be included to specify changes in parameter values during the simulation and the effective date of such changes. Each card contains the following data:

(1) Effective simulation month.

(2) Airman category identification: first-termer or career airmen

(3) Maximum time to ETS to be eligible for early-out at completion of

non-CONUS tour. Three different parameters may be specified, one for each of the three non-CONUS tour categories.

(4) Corresponding proportions of airmen eligible for early-out who accept early-out.

Relationship to output

These parameters, in conjunction with those specified on card type 22 for first-termers, determine the early outs selected in the model and reported in the CAROM output. For specific data items in the output which are directly influenced, see the description under card type 22.

x. Card type 24 — Decoration Distribution Card

Purpose and use

The purpose of this card type is to define the decoration scores awarded at tour completion for each of the four tour categories. These parameters are used in the model to update the decoration score of each airman upon tour completion. The decoration score accumulated by an airman and carried in his record is one of the Weighted Airman Promotion System (WAPS) factors. In conjunction with the other WAPS factors, the decorations determine an airman's WAPS score and, thereby, his promotability vis-a-vis other airmen in the same grade eligible for grade promotion. Different parameters may be specified for different periods of the simulation.

Format and content

The format is specified by Exhibit 25. One card of this card type must be submitted for each tour category, while one or more change cards may be included to specify the changes in parameter values during the simulation including their effective dates. Each card contains the following data:

(1) Effective simulation month.

(2) Tour category identification.

(3) Five different decoration scores awarded at tour completion.

(4) The corresponding proportions of airmen awarded each specific decoration score. Notice that for computational reasons, the proportions specified must be greater than zero (but may be finitely close to zero). The proportions specified on each card ought to add up to 1.0. However, any input specification errors will be compensated by the model as it automatically normalizes each distribution in the input stream such that the normalized proportions used by the model always add to 1.0.

Relationship to output

These parameters may affect an individual airman's promotability and, as such, do not influence the aggregate simulation results documented in the CAROM reports. The sole data item affected is the decoration score carried in each airman's record in the Loss File and the Personnel Status File.

y. Card type 25 — Promotion Strength Card

Purpose and use

The purpose of this card is to define the grade structure of the career area when the vacancy promotion system is utilized. The grade structure, in turn, determines upper bounds on the numbers of promotions to each grade during the simulation. The concept of promotion strength has been introduced to allow for promotion to the next higher grade above the highest authorized grade in the career area. This capability is necessary to simulate the attrition from the career area due to being promoted to a grade higher than the highest authorized grade. Promotion strength is equal to authorized strength plus desired strength of this next higher grade. If the E9 grade is authorized in the career area, then

promotion strength is equal to authorized strength.

Format and content

The format is specified by Exhibit 26A. Only one card must be submitted, while one or more change cards may be included to specify any parameter changes during the simulation including their effective dates. The content of this card is as follows:

(1) Effective simulation month

(2) Promotion strength

(3) Proportion of promotion strength authorized at each grade and above. The proportion for E2/1 and above is not specified because it is by definition equal to 1.0.

Relationship to output

When the vacancy promotion quota system is active these parameters strongly influence the numbers of promotions. Under constant promotion eligibility conditions, increasing the promotion strength leads to increasing the promotion flow. Items in the CAROM output directly affected by these parameters include the number of promotions reported in the Monthly Summary Report. Indirectly, these parameters, of course, affect the fill of billets, for example, the extent of grade substitution required to arrive at a maximal billet fill. These items are included in all three CAROM reports.

z. Card type 26 — Promotion Opportunity Card

Purpose and use

The purpose of this card is to specify an equal selection opportunity proportion of airmen to be promoted to each grade. Each proportion is multiplied by the number of airmen eligible for promotion to each respective grade to calculate the promotion quota for each grade. The presence of this card in the CAROM control card deck is optional. When this card is not present, the vacancy promotion quota system is active. When it is present the equal selection opportunity promotion quota system is active according to the time

specified in card columns 1-3.

Format and content

The format is specified by Exhibit 26B. If the equal selection opportunity promotion quota system is desired, only one card must be submitted, while one or more change cards may be included to specify any changed set of proportions, including their effective dates. The content of this card is as follows:

(1) Effective simulation month

(2) Proportion of airmen to be promoted to each grade who are eligible for such promotion.

Relationship to output

When the equal selection opportunity promotion quota system is active, these parameters strongly influence the numbers of promotions. Increasing one of these proportions will increase the number of promotions to the grade associated with that proportion. Changing the numbers of promotions will change the grade force structure, which will directly affect the numbers of assignments to grade or grade/skill assignment categories.

Figure 8: Check List for Control Card Deck

Card Type (columns 5-6)	Month (columns 1-3)	Number of Cards	Comments
01	0	1	Defines: L = length of run $\leq$ 360; type of run = G, S or B.
02	0	1	Defines: K = number of skill levels; N = number of grade/skill level comb. $\leq$ 28.
03	0	4	
04	0	X	For run type B: X = 4N; for run type G: X = 32; for run type S: X = 4K.
05	0	X	For run type B: X = 4N; for run type G: X = 32; for run type S: X = 4K.
06	0	X	For run type G or S: X = 4; for run type B: X = N
07	0	1	
08	0	1	
09	0	1	
10	0	1	
11	0	1	
12	0	7	
13	0	K	More cards are allowed up to 2K.
14	0	1	More cards are allowed.
15	0	1	More cards are allowed.
16	0	1	
17	0	3	
18	0	1	
19	0	X	For run type B: X = 4K; for run type G or S: X = 4.
20	0	8	
21	0	3	
22	0	1	
23	0	2	
24	0	4	
25	0	1	
8-25	1	variable	Any change cards for month 1 in card type order.
8-25	2	variable	Any change cards for month 2 in card type order.
⋮			
8-25	L	variable	Any change cards for the final month in card type order.

B. DESCRIPTION OF MODEL OUTPUT

CAROM simulation results are reported in the form of hard copy reports as well as data files stored on magnetic tape. The following types of reports are produced:

- Monthly Summary Report -- a summary of the supportability of the authorized strength for each tour category and the total numbers of accessions and promotions in the career area for each simulation month.
- Manning Level Report -- the fill of billets by tour category and grade or skill level for a specific simulation month.
- Assignment, Loss and Promotion Report -- by grade or skill level, the transfers between tour categories, the number of losses by type of attrition, and the total numbers promoted for a specific simulation interval.

The last two reports are optional, i.e., they are generated at intervals specified by the user (see card type 01). The content of each report type is described below; while report samples are provided in Exhibits 27 to 32. A summary of the relationships between CAROM input data and output data is provided by Figure 9.

Two data files are produced by CAROM:

- Loss File -- an accumulation of all airman records deleted from the the inventory during the simulation run.
- Status File -- containing all active records at the end of the simulation.

Both files are stored on the same physical magnetic tape in a BCD format suitable for further off-line processing if the model user wants to perform a special analysis of these records. The record format for the two files is identical and is specified by Exhibit 33.

Additional output of the CAROM model includes control card listings and error diagnostics. These items are discussed under Operator Output in Chapter V.

1. Monthly Summary Report

This report is divided into two major sections, summary data by tour category, and summary data for the total inventory. For each simulation month the following data are reported:

Figure 9:

INPUT–OUTPUT RELATIONSHIPS

CAROM INPUT		CAROM OUTPUT: MONTHLY SUMMARY REPORT — By tour category: Report type: grade or skill level	Per cent spaces filled	% filled from grade or skill above	% filled from grade or skill below	Assignments to tour	Assignments from tour	Overages or shortages	Losses from tour	Career area: Actual strength	Authorized strength	Number of accessions	Number of promotions
File or card type	Data Item												
Personnel Records	Number of records/entry date		D	D	D	D	D	D	D	D		D	D
	Airman characteristics		D	D	D	D	D	D	D	D			D
Permanent Data 01	Run parameters	D											
02	Legal skills and grade/skill level combinations		I	I	I	I		I					I
03	Permissible tour sequences		D			D	D	D					
04	Permissible grade/skill level substitutions		D			D	D	D					
05	Desirability level definitions (from 03 & 04)			D	D								
06	Sharing policy and priorities		D			D	D	D					
07	WAPS updating parameters												
08	Total authorized strength		I			I	I	I			D		
	Maximum CONUS overage								I	D			
	Exceptional attrition rate		I					I	I	D			I
	Minimum CONUS times		D			D		D					
	Maximum CONUS tour length		N			N		N					
	Proportion stabilized positions		D			D		D					
09	Minimum time in grade for promotion		I	I	I	I		I					D
10	Minimum time in skill level for promotion		I	I	I	I		I					D
11	Minimum time in service for promotion		I	I	I	I		I					D
12	WAPS factor weights												
13	Skill level promotion distribution		I	I	I	I		I					D
14/15	Reenlistment terms distribution (FT and C)		I					I		I			
16	Minimum promotion obligation		I					I		D			
17	Retention rates		D			I		D	D	D			D
18	Up-or-out policy parameters		D					D	D	D			D
19	Authorized billets		D			D	D	D			D		
20	Tour length distribution		D			D	D	D					
21	Assignment eligibility parameters		D			D	D	D					
22	General early-out parameters		D			D	D	D	D	D			D
23	Tour completion early-out parameters		D			D	D	D	D	D			D
24	Decorations distribution												
25	Promotion strength		I			I		I					D

CAROM OUTPUT: MANNING LEVEL REPT. — By tour and grade or skill level: Output of report and report type	Actual strength	Authorized strength	Overage or shortage	Percent spaces filled	% filled from grade or skill above	% filled from grade or skill below	ASGMT/LOSS/PROM. REPORT — By tour and grade or skill level: Output of report and report type	Moves to	Transfers from	Total losses	Non-reenlistment	Exceptional attrition	Early out	Up-or-out	CONUS excess losses	GS: Promotions	LOSS FILE: Number of records	Airman characteristics	Type of loss: 1—Up-or-out loss	2—Non-reenlistment	3—Exceptional attr.	4—General early-out	5—Tour early-out	6—CONUS excess loss	PERS. STATUS F.: Number of records	Airman characteristics
	D		D	D	D	D		D	D	D	D	D	D	D	D	D	D		D						D	
	D		D	D	D	D		D	D	D	D	D	D	D	D	D			I							D
D							D										D								D	
	I		I	I	I	I		I									I									I
	D			D	D	D		D	D										I							I
	D			D	D	D		D	D										I							I
			D												D	D			I							D
	D			D	D	D		D	D										I							I
	I	D	I	I				I	I	I					I			I		I				I		
										D						I		I							D		
	I		I	I								D						I				D				
	D			D				D										I								
	N		N	N				N										N								
	D		D	D				D										D								
	I		I	I	I	I		I										I								D
	I		I	I	I	I		I										I								D
	I		I	I	I	I		I										I								D
	I		I	I		I		I										I								D
	I		I	I				I		I	I															D
	I		I	I				I		D								I								D
	D		D	D				I		D							D	D			D				D	
	D		D	D				I		D					D		D	D		D					D	
	D		D	D				D	D									I		I				I		D
	D		D	D				D	D	D							D	D				D			D	
	D		D	D				D	D	D							D	D					D		D	
																			I							D
	I		I	I				I									D	I								D

Key: D = direct effect. I = indirect effect. N = negligible effect (direct).

- By tour category:
  - — per cent of total spaces filled
  - — per cent billets filled through grade or skill level substitution, divided into two categories: - per cent filled from grades or skill levels above
    - per cent filled from grades or skill levels below.
  - — number of assignments to tour category
  - — number assigned from tour category
  - — overages or shortages with respect to authorized strength
  - — total losses from tour category.
- Total career area:
  - — on-board or actual strength
  - — authorized strength
  - — number of accessions
  - — number of promotions.

The report is formatted so as to facilitate comparison of like items of information across projection increments, i.e., data relating to each of six simulation months appear on each page of the report. Because the report is produced for each simulation time increment, the CAROM user is provided with an "audit trail" of the processing of airmen throughout the simulation.

Most of the data elements reported are self-explanatory. The per cent billet fill achieved through grade of skill level substitution is broken down by the direction of grade or skill level substitution, down or up. Thus, the column heading "Per cent filled from grade (or, skill levels) above" applies to the total number of billets filled by airmen with a higher grade or skill level than the billet grade or skill level in relation to the total number of billets authorized for the tour category concerned. The reverse applies to the column headed "Per cent filled from grades (or, skill levels) below."

For run types involving grades only or grade/skill level combinations, the substitutions and promotions reported in this report refer to grade substitutions and grade promotions (Exhibit 27). For run types involving skill levels only, reference

is made to skill level substitutions and skill level promotions (Exhibit 28). Notice that the concept of substitution allows for reporting an overage at the same time that the per cent fill is less than 100%.

The column heading "Losses from Tour" refers to all types of attrition incurred during the simulation month by tour category. These losses do not include the reassignments at tour completion reported under the "Assignments from Tour" column, but do include, for example, tour completion early outs or any other type of attrition.

2. Manning Level Report

This report is automatically produced for the initial allocation (simulation month 0). For subsequent periods, the report is optional. It will be produced at the end of a user-specified simulation time interval (see card type 01) in conjunction with the Assignment, Loss and Promotion Report applicable to that interval. It is available by grade (Exhibit 29) and/or skill level (Exhibit 30) aggregation, depending on the type of run specified by the model user (card type 01).

The report is organized by grade or skill level and by tour category and includes the following data:

- on-board or actual strength
- authorized strength
- overages or shortages
- per cent of total spaces filled
- per cent of spaces filled from grades or skill levels above
- per cent of spaces filled from grades or skill levels below.

The same items of information are also reported across tour category by grade or skill level and across grade or skill level by tour category, thus providing summaries by tour category and grade or skill. Grade or skill level substitutions will, of course, only take place to the extent necessary to achieve maximum billet fill and are subject to user-specified grade or skill substitution policies. Shortages in assignment categories are reported as negative overages.

3. Assignment, Loss and Promotion Report

This report is an optional report. It will be produced in accordance with user specifications (see card type 01) in conjunction with the corresponding Manning Level Report. The report is an accumulation of the events occurring during a user-specified simulation interval (printed at the top of the page) as opposed to a single simulation month. The report is organized by grade (Exhibit 31) or skill level (Exhibit 32) and tour category and provides the following information:

- number of assignments to tour category
- number transferred from tour category
- total losses
- losses broken down by type of loss:
  (1) up-or-out
  (2) ETS losses
  (3) exceptional attrition
  (4) general early out
  (5) tour completion early out
  (6) CONUS overage losses.

The same items of information are also reported across tour category and across grade or skill level, thus providing summary totals by grade or skill level and by tour category.

The bottom part of the report provides the total number of promotions by grade or skill level (no breakdown by tour category). For example, the number entered under the E8 column refers to the number of promotions from E8 to E9 during the given interval (regardless whether the airmen involved are still in the inventory or not).

One additional item of information - the total number of new accessions during the time interval specified - is included at the top of each page of the report.

4. Loss and Personnel Status Files

The Loss and Personnel Status files are stored in BCD format on magnetic tape, with an end-of-file mark separating the two files. The following data are provided in each record:

- time of drop: loss date (simulation month) for losses or final simulation month for on-board airmen

- time in service at time of drop
- first termer/careerist flag
- ETS
- grade at time of loss
- skill at time of loss
- number of months in grade
- date of skill level (simulation month)
- tour history at loss date (previous and present tour category)
- tour completion date for current tour
- assignment history
- exceptional attrition date
- loss code
- WAPS factors (SKT, PFE, APR, Decorations and the two unused factors).

The Assignment History field includes the numbers of previous (including present) tours in each of the three non-CONUS tour categories as well as the most recent tour completion dates in each tour category. The loss code identifies the type of loss: exceptional attrition, early out, up-or-out, normal ETS loss or retirement (voluntary or mandatory), or CONUS excess loss. If the record is not a loss record but refers to an airman on-board in the final month of simulation, the loss code is zero. The record format is specified by Exhibit 33. The recording mode is always even parity, external BCD and, normally, 7 track, 556 BPI. However, the last two items are controllable via the appropriate SCOPE control cards (see Chapter V). If subsequent processing of tape file 7 is to take place on the CDC 6600, the operator is advised to use the above parameters. The logical record length is 60 characters. Logical records are blocked with a blocking factor of 75 to achieve physical records of 4500 characters, except for the final records on the file.

V. OPERATOR INSTRUCTIONS

A. RUN SUBMISSION

The Career Area Rotation Model (CAROM) is currently operating on a Control Data Corporation 6600 computer located in the CDC Data Services, Rockville Cybernet Center, Rockville, Maryland. The program operates under the SCOPE operating system for the CDC 6600 computer. The SCOPE system is a complex operating system which requires specially trained operators, and for this reason users are not allowed direct access to the computer. The functions of tape staging and accounting normally accomplished by the operator on smaller machines are accomplished instead through special SCOPE control cards. The sequence, content and format of the SCOPE control cards required to load and run the CAROM model are described below in detail in the order in which they must appear in the SCOPE control deck.

The SCOPE control deck precedes the CAROM control card deck prepared by the model user. All SCOPE control cards begin in card column 1 and are punched free field with the various parameters on the cards separated by commas, periods or parentheses. Exhibit 34 illustrates a complete CAROM deck structure including the contents of the SCOPE control deck.

1. SEQUENCE CARD

The sequence card is used to identify the job during processing. If a job is submitted to the computer center with an old sequence card, it may be replaced by the center operator for bookkeeping purposes.

Example: $SEQUENCE, nnn.

Where: nnn is an arbitrary three digit alphanumeric identifier.

2. CHARGE CARD

The charge card is used to establish and verify accounting information. The account number is check-summed and verified to insure that it is correct

and any error in the format of the charge card or in the account number itself will cause an immediate termination of the job.

Example: $CHARGE,nnnnnnn-AFC.

Where: nnnnnnn is the account number to which charges accumulated for this job will be billed.

3. THE JOB CARD

The job card is used to establish the basic hardware parameters to be used for the job. The four parameters contained on the card establish:

a. The number of memory words required by the CAROM run.

b. The number of tape drives to be used by the CAROM run.

c. The maximum computer time to be used by the CAROM run.

d. The priority of the job.

The specific priority used determines the speed in which the job is turned around and the price per second charged for computer time.

Example: AFC(CM150000,TPxx,Tyyy,Pz)

Where: xx equals the number of tapes to be used by the job. This number is equal to the number of request cards submitted for the job (see 4 below).

yyy is the maximum allowable running time for the job in octal seconds. A reasonable time limit may be established for the simulation run by multiplying the number of simulation months$_8$ to be run time 400$_8$.

z is a priority code, the following codes are available:

z = 6 - Express (2 hour)
4 - Standard (4 hour)
2 - Deferred (24 hour)
0 - Economy (weekend).

The given turnaround times are average values -- actual turnaround time depends on the CDC 6600 system load.

Notice that the memory allocation (CM) must agree with the field length specified in CAROM card type 01. For estimating the memory size required for a given number of airmen and length of simulation, see Chapter IV, A, 2, a.

4. REQUEST CARD

Request cards are used to assign program logical tape units to physical tape units. Each request card defines a tape drive to be used. There are a maximum of five tape drives that may be required by the CAROM model. A minimum of two tape drives is required, with the remaining three drives being optionally assigned, depending upon the specific inputs and outputs required by the CAROM user. Each request card and its associated function is listed below:

a. REQUEST,CAROM. (XXX/NORING)

Where: xxx is the visual reel number of the CAROM load-and-go tape.

This request card is always required.

b. REQUEST, TAPE9,S. (XXX/NORING)

Where: xxx is the visual reel number of the tape containing the personnel data records.

This request card is always required.

c. REQUEST,TAPE7. (SAVE)

This request card should be used only if the user wants the personnel status records and loss records loaded onto tape 7 for later processing off-line. Without the card, these records will not be available to the model user.

d. REQUEST,TAPE4.(SAVE)

This request card directs the operator to save the tape containing the optional reports produced by CAROM. This request card should be used only when the user wants to save the simulation results on tape in addition to the hard copy CAROM reports.

e. REQUEST,TAPE8.(SAVE)

This request card directs the operator to save the tape containing the control card listing, the error messages and the Monthly Summary Reports

produced by CAROM. This request card should be used only when the user wants to save these data on tape in addition to the hard copy reports and listings produced in this CAROM run.

5. OTHER SCOPE CARDS

Remaining SCOPE control cards are illustrated in Exhibit 34 exactly as they should be prepared. These cards direct SCOPE to load and execute CAROM and to copy any CAROM reports produced onto the SCOPE output unit (printer). The SCOPE cards are terminated with an end-of-file card containing a 7, 8, 9 multipunch in card column 1.

6. CAROM CONTROL CARD DECK

The CAROM control dard deck is input following the SCOPE control deck as illustrated in Exhibit 34. This deck should be prepared in accordance with the instructions given in Chapter IV, A.

7. TERMINATION OF INPUT

The entire deck should be terminated with a card containing 6, 7, 8, 9 punches in card column 1. If this card is not present, it will be added to the deck by the operator.

B. OPERATOR OUTPUT

Control Card List and Diagnostics

All control cards input to the model are listed on the output file. Diagnostics of any control card errors are listed immediately following the control card in error. Data items in error are identified by arrows pointing to the error. If no fatal input errors are present, the run proceeds with processing the personnel data records. Any errors discovered in these records are also listed in the diagnostics. These errors are, however, never fatal; the record involved is simply ignored. A sample of the control card listing is provided by Exhibit 35. All diagnostic messages are listed in Exhibit 36. All error messages indicate a fatal error (except type 9 errors for data records) causing termination of the run.

Exhibit 1

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: PERSONNEL RECORD — I/O: INPUT

DATA IDENTIFICATION: — Page 1 of 1

Character position	Description	Comments
1-4	Date of first enlistment	$-360 \leq X \leq 360$
5-7	Termination of current enlistment obligation (ETS)	$0 \leq X \leq 432$
8-11	Date of rank	$-360 \leq X \leq 360$
12	Current tour category	R, S, A or C
13-15	Projected date available for reassignment (TCD)	$0 \leq X \leq 432$
16-17	Number of previous remote tours	$0 \leq X \leq 31$
18-21	Date of completion of most recent remote tour	$-360 \leq X \leq 0$ or blank (no tour)
22-23	Number of previous special tours	$0 \leq X \leq 31$
24-27	Date of completion of most recent special tour	$-360 \leq X \leq 0$ or blank (no tour)
28-29	Number of previous accompanied tours	$0 \leq X \leq 31$
30-33	Date of completion of most recent accompanied tour	$-360 \leq X \leq 0$ or blank (no tour)
34-35	Number of previous CONUS tours	$0 \leq X \leq 31$
36-39	Date of completion of most recent CONUS tour	$-360 \leq X \leq 0$ or blank (no tour)
40	Skill level	$2 \leq X \leq 9$
41	Current grade	$1 \leq X \leq 9$
42-44	Number of months at skill level	$0 \leq X \leq 360$
45-47	Specialty Knowledge Test (SKT)	$0 \leq X \leq 100$
48-50	Promotion Fitness Examination (PFE)	$0 \leq X \leq 100$
51-52	Airman Proficiency Rating (APR)	$0 \leq X \leq 90$
53-54	Decorations Score (DEC)	$0 \leq X \leq 25$
55-57	Unspecified WAPS factor 1	$0 \leq X \leq 100$
58-60	Unspecified WAPS factor 2	$0 \leq X \leq 100$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The start of a simulation run is assumed to be time 0. All date information in personnel records is assumed to be in simulation time units (months) relative to time 0 and must be consistent with the date of entry established by the record sequence.

(3) Date of enlistment in terms of simulation months must reflect the total amount of previous active service, if any.

(4) The number of previous tours specified for airmen in the initial, on-board population must include their current tour. For example, an airman initially on an accompanied tour ("A" in position 12) must have at least one accompanied tour specified as the number of previous accompanied tours ("1" or more in positions 28-29, right-justified).

Exhibit 2

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 01 — I/O: INPUT

DATA IDENTIFICATION: RUN PARAMETER CARD — Page 1 of 1

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "01"
8	Type of run	S, G or B
10-45	User specified report heading	Any alphanumerics
46-51	Date of reports	Integer YYMMDD
52-57	Length of simulation run	$1 \leq X \leq 360$ (months)
58-60	Time of first detailed optional report	Blank or $1 \leq X \leq 360$
61-63	Interval between successive detailed optional reports	Blank or $1 \leq X \leq 360$
65	Request for Manning Level Report by Grade	Any alphanumeric or blank
66	Request for Manning Level Report by Skill Level	Any alphanumeric or blank
67	Request for Assignment, Loss and Promotion Report by Grade	Any alphanumeric or blank
68	Request for Assignment, Loss and Promotion Report by Skill Level	Any alphanumeric or blank
70-75	Maximum field length	In octal

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) If report date field is left blank, then the current date of run is used.

(3) If columns 58-68 are left blank, no optional reports will be generated, i.e., only the Monthly Summary Reports will be produced.

(4) If any "Request for Report" column (65-68) is left blank, that report will not be generated.

(5) Column 8 is used to denote the type of run (S = skill level only, G = grade only, and B = grade and skill level combination).

(6) Field length is computer jargon for memory size allocated to job. See text for instructions.

Exhibit 3

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 02 — I/O: INPUT

DATA IDENTIFICATION: LEGAL SKILLS AND GRADE/SKILL COMBINATIONS CARD — Page 1 of 1

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "02"
10-17	List of legal skill levels	Number of levels ≤ 8
21	Lowest legal skill level for grade E9	$2 \leq X \leq 9$
23	Highest legal skill level for grade E9	$2 \leq X \leq 9$
27	Lowest legal skill level for grade E8	$2 \leq X \leq 9$
29	Highest legal skill level for grade E8	$2 \leq X \leq 9$
33	Lowest legal skill level for grade E7	$2 \leq X \leq 9$
35	Highest legal skill level for grade E7	$2 \leq X \leq 9$
39	Lowest legal skill level for grade E6	$2 \leq X \leq 9$
41	Highest legal skill level for grade E6	$2 \leq X \leq 9$
45	Lowest legal skill level for grade E5	$2 \leq X \leq 9$
47	Highest legal skill level for grade E5	$2 \leq X \leq 9$
51	Lowest legal skill level for grade E4	$2 \leq X \leq 9$
53	Highest legal skill level for grade E4	$2 \leq X \leq 9$
57	Lowest legal skill level for grade E3	$2 \leq X \leq 9$
59	Highest legal skill level for grade E3	$2 \leq X \leq 9$
63	Lowest legal skill level for grade E2/1	$2 \leq X \leq 9$
65	Highest legal skill level for grade E2/1	$2 \leq X \leq 9$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) There is a maximum of 28 legal grade/skill combinations allowed by the model. Any more than this will cause the model to abort with the proper diagnostic message.

(3) The list of skill levels (columns 10-17) simply defines each level recognized by the model, i.e., up to eight different integers in any order, with the lowest skill level denoted by "2" or higher and the highest by "9" or lower.

Exhibit 4

FORMAT SPECIFICATION

SYSTEM: CAROM
DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 03
I/O: INPUT

DATA IDENTIFICATION: TOUR SEQUENCE DESIRABILITY CARD
Page 1 of 1

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "03"
8	Tour identification (subsequent tour)	R, S, A or C
10-12	Remote-Remote-Tour ID	A thru P or blank
13-15	Remote-Speciol-Tour ID	A thru P or blonk
16-18	Remote-Accompanied-Tour ID	A thru P or blank
19-21	Remote-CONUS-Tour ID	A thru P or blank
22-24	Special-Remote-Tour ID	A thru P or blank
25-27	Special-Special-Tour ID	A thru P or blank
28-30	Special-Accompanied-Tour ID	A thru P or blank
31-33	Special-CONUS-Tour ID	A thru P or blank
34-36	Accompanied-Remote-Tour ID	A thru P or blank
37-39	Accompanied-Special-Tour ID	A thru P or blank
40-42	Accompanied-Accompanied-Tour ID	A thru P or blank
43-45	Accompanied-CONUS-Tour ID	A thru P or blank
46-48	CONUS-Remote-Tour ID	A thru P or blank
49-51	CONUS-Special-Tour ID	A thru P or blonk
52-54	CONUS-Accompanied-Tour ID	A thru P or blank
55-57	CONUS-CONUS-Tour ID	A thru P or blank

NOTES: (1) Columns/character positions not referenced are irrelevant and left blonk or may be used for user comments/identification purposes.

(2) User must submit one card of this type for each tour.

(3) Fields 10-12, etc. are designed to indicate the relative desirability of permissible tour sequences consisting of the past and present tour specified for each field with respect to the subsequent tour identified by card column 8. Relative desirability is specified by an alpha character between A and P, with A denoting the most desirable tour sequence. Impermissible tour sequences must be left blank.

Exhibit 5

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 04 I/O: INPUT

DATA IDENTIFICATION: GRADE/SKILL LEVEL SUBSTITUTION CARD Page 1 of 1

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "04"
7	Tour identification	R, S, A, C or Blank
8	Grade	$2 \leq x \leq 9$ or blank
9	Skill level	$2 \leq x \leq 9$ or blank
11	(B) Grade of the 1st desired substitution	$2 \leq x \leq 9$ or blank
12	(B) Skill level of the 1st desired substitution	$2 \leq x \leq 9$ or blank
14	(C) Grade of the 2nd most desired substitution	$2 \leq x \leq 9$ or blank
15	(C) Skill level of 2nd most desired substitution	$2 \leq x \leq 9$ or blank
17	(D) Grade of the 3rd most desired substitution	$2 \leq x \leq 9$ or blank
18	(D) Skill level of the 3rd most desired substitution	$2 \leq x \leq 9$ or blank
20	(E) Grade of the 4th most desired substitution	$2 \leq x \leq 9$ or blank
21	(E) Skill level of the 4th most desired substitution	$2 \leq x \leq 9$ or blank
23	(F) Grade of the 5th most desired substitution	$2 \leq x \leq 9$ or blank
24	(F) Skill level of the 5th most desired substitution	$2 \leq x \leq 9$ or blank
⋮		
59	(R) Grade of the 17th most desired substitution	$2 \leq x \leq 9$ or blank
60	(R) Skill level of the 17th most desired substitution	$2 \leq x \leq 9$ or blank
62	(S) Grade of the 18th most desired substitution	$2 \leq x \leq 9$ or blank
63	(S) Skill level of the 18th most desired substitution	$2 \leq x \leq 9$ or blank
65	(T) Grade of the 19th most desired substitution	$2 \leq x \leq 9$ or blank
66	(T) Skill level of the 19th most desired substitution	$2 \leq x \leq 9$ or blank

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) If the tour identification is left blank in card column 7, then the model assumes that the card applies to all tour types.

(3) The model implicitly assumes that grade/skill level substitutions must be minimized, i.e., on-grade and on-skill level specifications (level "A" substitutions) are not included in the list of possible grade substitutions.

(4) If no grade/skill level substitutions are allowed, all fields (11-66) should be left blank. If more than one substitution is allowed for a specific grade/skill level combination, they should be ordered consecutively, e.g., the B-level and D-level may not have an entry while the C-level is blank. If either grade or skill level only is specified, use the appropriate columns (11 or 12 through 65 or 66) to enter the desired substitutions. Columns 8 and 9 may not both be left blank: either one or both must have an entry depending on the type of run.

Exhibit 6

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 05 — I/O: INPUT

DATA IDENTIFICATION: LEVEL DEFINITION CARD — Page 1 of 1

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "05"
7	Tour identification	R, S, A, C or blank
8	Grade identification	$2 \leq X \leq 9$ or blank
9	Skill level	$2 \leq X \leq 9$ or blank
10	The least desirable grade/skill level substitution for Level 1	A through T or blank
11	The least desirable tour sequence for Level 1	A through P or blank
12	The least desirable grade/skill level substitution for Level 2	A through T or blank
13	The least desirable tour sequence for Level 2	A through P or blank
14	The least desirable grade/skill level substitution for Level 3	A through T or blank
15	The least desirable tour sequence for Level 3	A through P or blank
16	The least desirable grade/skill level substitution for Level 4	A through T or blank
17	The least desirable tour sequence for Level 4	A through P or blank
. . .		
76	The least desirable grade/skill level substitution for Level 34	A through T or blank
77	The least desirable tour sequence for Level 34	A through P or blank
78	The least desirable grade/skill level substitution for Level 35	A through T or blank
79	The least desirable tour sequence for Level 35	A through P or blank

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The rank ordered series of 2-digit grade/skill level/tour history specifications for each tour/grade/skill level combination specified in columns 7-9 define the "levels of fit" optimized in the Allocator. Level 1 represents the best level of fit and defines the grade/skill level(s) and tour history(ies) which are deemed most desirable for assignment to the billet category specified in columns 7-9. Each subsequent level represents a relaxation of these requirements to be met by airmen assigned to that billet category, with Level 35 (or, the lowest one used) representing the worst level of fit, defining the minimum prerequisites for assignment to that billet category. The alpha characters entered for each level refer to the specifications in card types 3 and 4. Each level is defined in terms of the least desirable substitution and tour history to qualify for that level: the higher ranked substitutions and/or tour histories are by implication included in that level.

(3) If the tour identification is left blank in column 7, the model assumes that the card applies to all tour types. Either column 8 or column 9, or both, must have an entry depending on the type of run; both may not be left blank simultaneously.

Exhibit 7

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 06 I/O: INPUT

DATA IDENTIFICATION: SHARING POLICY AND PRIORITY LEVEL CARD Page 1 of 2

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "06"
8	Tour Identification	R, S, A or C
10-15	Sharing coefficient for E9 or skill level 9	$.0001 \leq X \leq 1000.0$
16-21	Sharing coefficient for E8 or skill level 8	$.0001 \leq X \leq 1000.0$
22-27	Sharing coefficient for E7 or skill level 7	$.0001 \leq X \leq 1000.0$
28-33	Sharing coefficient for E6 or skill level 6	$.0001 \leq X \leq 1000.0$
34-39	Sharing coefficient for E5 or skill level 5	$.0001 \leq X \leq 1000.0$
40-45	Sharing coefficient for E4 or skill level 4	$.0001 \leq X \leq 1000.0$
46-51	Sharing coefficient for E3 or skill level 3	$.0001 \leq X \leq 1000.0$
52-57	Sharing coefficient for E1/E2 or skill level 2/1	$.0001 < X < 1000.0$
58-59	Priority level for E9 or skill level 9	$1 \leq X \leq 32$
60-61	Priority level for E8 or skill level 8	$1 \leq X \leq 32$
62-63	Priority level for E7 or skill level 7	$1 \leq X \leq 32$
64-65	Priority level for E6 or skill level 6	$1 \leq X \leq 32$
66-67	Priority level for E5 or skill level 5	$1 \leq X \leq 32$
68-69	Priority level for E4 or skill level 4	$1 \leq X \leq 32$
70-71	Priority level for E3 or skill level 3	$1 \leq X \leq 32$
72-73	Priority level for E2 or skill level 2/1	$1 \leq X \leq 32$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This format applies to run type G (grade only) or S (skill level only). The format for run type B (both grade and skill level) is different and is specified on the next page.

(3) One and only one card must be submitted for each tour.

(4) See Appendix A for a description of the sharing coefficients. They may be derived by the user through manually solving a simple distribution problem. For example, assume that in each grade there are 100 vacancies (a total of 800 vacant billets) and that 600 men are available for those billets. Assume further that grade substitution is unlimited. By indicating how these 600 men would be assigned to the 800 billets, the sharing coefficients may be computed as the number assigned to billet category divided by the remaining vacancies in the billet category.

Exhibit 7

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 06 I/O: INPUT

DATA IDENTIFICATION: SHARING POLICY AND PRIORITY LEVEL CARD Page 2 of 2

Card Column	Description	Comments
1-3		Literal "000"
5-6	Card identification	Literal "06"
8	Skill level	$2 \leq x \leq 9$
9	Grade	$2 \leq x \leq 9$
10-15	Sharing coefficient for Remote tour	$.0001 \leq x \leq 1000.0$
16-21	Sharing coefficient for Special tour	$.0001 \leq x \leq 1000.0$
22-27	Sharing coefficient for Accompanied tour	$.0001 \leq x \leq 1000.0$
28-33	Sharing coefficient for CONUS tour	$.0001 \leq x \leq 1000.0$
34-39	Priority level for Remote tour	$1 \leq x \leq 32$
40-45	Priority level for Special tour	$1 \leq x \leq 32$
46-51	Priority level for Accompanied tour	$1 \leq x \leq 32$
52-57	Priority level for CONUS tour	$1 \leq x \leq 32$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This format applies to run type B (both grade and skill level). If the run type is G (grade only) or S (skill level only) use the alternate format specified on the previous page.

(3) See Appendix A for a description of the sharing coefficients. They may be derived by the user through manually solving a simple distribution problem. For example, assume that in each grade/skill level there are 100 vacancies (a total of up to 2800 vacant billets depending on the number of legal grade/skill combinations) and that the number of men available for those billets amounts to only 75% of the number of vacant billets. Assume further that grade/skill level substitution is unlimited. By indicating how these men would be assigned to the billets, the sharing coefficients may be computed as the number assigned to the billet category divided by the remaining vacancies in the billet category.

(4) One card must be submitted for each legal grade/skill level combination.

Exhibit 8

FORMAT SPECIFICATION

SYSTEM: CAROM | DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 07 | I/O: INPUT

DATA IDENTIFICATION: WAPS UPDATING DATA CARD | Page 1 of 1

Card Column	Description	Comments
1- 3		Literal "000"
5- 6	Card identification	Literal "07"
10-15	Updating interval	$1 \leq X \leq 360$
16-21	Standard deviation of Specialty Knowledge Test (SKT)	$0.0 \leq X \leq 99.0$
22-27	Standard deviation of Promotion Fitness Examination (PFE)	$0.0 \leq X \leq 99.0$
28-33	Standard deviation of Airman Proficiency Rating (APR)	$0.0 \leq X \leq 99.0$
34-39	Standard deviation of unspecified factor 1	$0.0 \leq X \leq 99.0$
40-45	Standard deviation of unspecified factor 2	$0.0 \leq X \leq 99.0$
46-51	Maximum Decorations Score	$0 \leq X \leq 99.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The updating interval determines in what month of the simulation the WAPS factors (SKT, PFE, APR and the two unspecified factors) are updated in all records which are present at that time in the model. For example, if interval is 12, then all records are updated in the 12th, 24th, etc. month of simulation, including new accessions which entered, say, in month 11.

(3) The Decorations Scores are updated at tour completion and are not subject to this updating interval.

Exhibit 9

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 08 — I/O: INPUT

DATA IDENTIFICATION: MODEL PARAMETER AND ELIGIBILITY CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "08"
10-15	Authorized strength	Integer
16-21	Exceptional attrition rate	$0.0 \leq X \leq 1.0$
33	----------→	Literal "0"
34-39	Minimum time in CONUS before a remote tour	$0 \leq X \leq 360$ (months)
40-45	Minimum time in CONUS before a special tour	$0 \leq X \leq 360$ (months)
46-51	Minimum time in CONUS before an accompanied tour	$0 \leq X \leq 360$ (months)
52-57	Maximum time in CONUS before reassignment in CONUS (or, maximum CONUS tour length)	$1 \leq X \leq 360$ (months)
58-63	Maximum allowable overage as proportion of authorized strength	$0.0 \leq X \leq 5.0$
64-69	Proportion of airmen assigned to CONUS who receive CONUS fixed-length tours	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

Exhibit 10

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 09 — I/O: INPUT

DATA IDENTIFICATION: MINIMUM TIME IN GRADE CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "09"
10-15	Minimum time E8 to E9	$1 \leq X \leq 360$ (months)
16-21	Minimum time E7 to E8	$1 \leq X \leq 360$ (months)
22-27	Minimum time E6 to E7	$1 \leq X \leq 360$ (months)
28-33	Minimum time E5 to E6	$1 \leq X \leq 360$ (months)
34-39	Minimum time E4 to E5	$1 \leq X \leq 360$ (months)
40-45	Minimum time E3 to E4	$1 \leq X \leq 360$ (months)
46-51	Minimum time E1/E2 to E3	$1 \leq X \leq 360$ (months)

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The numbers entered in columns 10-51 should represent the minimum number of manths on airman must remain in grade before becoming eligible for promotion to next higher grade.

Exhibit 11

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 10 — I/O: INPUT

DATA IDENTIFICATION: MINIMUM TIME IN SKILL LEVEL CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "10"
10-15	Minimum time in skill level 8 before eligible for promotion	$1 \leq X \leq 360$ (months)
16-21	Minimum time in skill level 7 before eligible for promotion	$1 \leq X \leq 360$ (months)
22-27	Minimum time in skill level 6 before eligible for promotion	$1 \leq X \leq 360$ (months)
28-33	Minimum time in skill level 5 before eligible for promotion	$1 \leq X \leq 360$ (months)
34-39	Minimum time in skill level 4 before eligible for promotion	$1 \leq X \leq 360$ (months)
40-45	Minimum time in skill level 3 before eligible for promotion	$1 \leq X \leq 360$ (months)
46-51	Minimum time in skill level 2/1 before eligible for promotion	$1 \leq X \leq 360$ (months)

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The numbers entered in columns 10-51 should represent the minimum number of months an airman must remain in skill level before becoming eligible for promotion to the next higher skill level.

Exhibit 12

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 11 — I/O: INPUT

DATA IDENTIFICATION: MINIMUM TIME IN SERVICE CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "11"
10-15	Minimum time in service to E9	$0 \leq X \leq 360$ (months)
16-21	Minimum time in service to E8	$0 \leq X \leq 360$ (months)
22-27	Minimum time in service to E7	$0 \leq X \leq 360$ (months)
28-33	Minimum time in service to E6	$0 \leq X \leq 360$ (months)
34-39	Minimum time in service to E5	$0 \leq X \leq 360$ (months)
40-45	Minimum time in service to E4	$0 \leq X \leq 360$ (months)
46-51	Minimum time in service to E3	$0 \leq X \leq 360$ (months)

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The numbers entered in columns 10-51 should represent the minimum number of months an airman must be in service (i.e., since date of first enlistment) before becoming eligible for promotion to the specified grade.

Exhibit 13

FORMAT SPECIFICATION

SYSTEM: CAROM
DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 12
I/O: INPUT

DATA IDENTIFICATION: WAPS FACTOR WEIGHTS CARD

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$
5-6	Card identification	Literal "12"
8	Grade from which promoted	$2 \leq X \leq 8$
10-15	Weight for Specialty Knowledge Test	$0.0 \leq X \leq 100.0$
16-21	Weight for Promotion Fitness Examination	$0.0 \leq X \leq 100.0$
22-27	Weight for Airman Proficiency Rating	$0.0 \leq X \leq 100.0$
28-33	Weight for Decorations Score	$0.0 \leq X \leq 100.0$
34-39	Weight for unspecified factor 1	$0.0 \leq X \leq 100.0$
40-45	Weight for unspecified factor 2	$0.0 \leq X \leq 100.0$
46-51	Weight for time in grade	$0.0 \leq X \leq 100.0$
52-57	Weight for time in service	$0.0 \leq X \leq 100.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) One card for each grade is required (except for E9).

(3) The grade specified is the current grade of an airman who is up for promotion (i.e., meets the mandatory prerequisites) to the next higher grade.

Exhibit 14

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 13 — I/O: INPUT

DATA IDENTIFICATION: SKILL LEVEL PROMOTION DISTRIBUTION CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "13"
8	Skill level	
10-15	Number of months from time airman became eligible for next skill level to award of next higher level	$0 \leq X \leq 360$ (months)
16-21	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
22-27	Number of months from time airman became eligible for next skill level to award of next higher level	$1 \leq X \leq 360$ (months)
28-33	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
34-39	Number of months from time airman became eligible for next skill level to award of next higher level	$1 \leq X \leq 360$ (months)
40-45	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
46-51	Number of months from time airman became eligible for next skill level to award of next higher level	$1 \leq X \leq 360$ (months)
52-57	Corresponding proportion for term above.	$0.0001 \leq X \leq 1.0$
58-63	Number of months from time airman became eligible for next skill level to award of next higher level	$1 \leq X \leq 360$ (months)
64-69	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This card type is analogous to card type 14 but applies to skill level promotion. The distribution of the time interval between eligibility for and award of next skill level is specified in terms of discrete time intervals and the proportion associated with each interval. Notice that the proportions must be greater than zero.

(3) At least one card for each skill level is required (except for the highest legal skill level). The user may input multiple cards of this type for the same skill level to specify the distribution if more than five time intervals are necessary. A maximum of 2 cards per skill level may be specified.

Exhibit 15

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 14 I/O: INPUT

DATA IDENTIFICATION: FIRST TERMER REENLISTMENT DISTRIBUTION CARD Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "14"
10-15	Term	$1 \leq X \leq 72$ (months)
16-21	Corresponding proportion of reenlistees with term above	$0.0001 \leq X \leq 1.0$
22-27	Term	$1 \leq X \leq 72$ (months)
28-33	Corresponding proportion of reenlistees with term above	$0.0001 \leq X \leq 1.0$
34-39	Term	$1 \leq X \leq 72$ (months)
40-45	Corresponding proportion of reenlistees with term above	$0.0001 \leq X \leq 1.0$
46-51	Term	$1 \leq X \leq 72$ (months)
52-57	Corresponding proportion of reenlistees with term above	$0.0001 \leq X \leq 1.0$
58-63	Term	$1 \leq X \leq 72$ (months)
64-69	Corresponding proportion of reenlistees with term above	$0.0001 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This card type defines the distribution of first termer reenlistment obligations. The distribution is specified by two numbers associated with each type of reenlistment. The first number specifies the length in months of the new reenlistment term, while the second number specifies the proportion of reenlistees with this reenlistment term. Notice that the proportions must be greater than zero.

(3) The user may input multiple cards of this type to specify the distribution if more than five different reenlistment terms must be simulated.

Exhibit 16

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 15 I/O: INPUT

DATA IDENTIFICATION: CAREERIST REENLISTMENT DISTRIBUTION CARD Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "15"
10-15	Term	$1 \leq X \leq 72$ (months)
16-21	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
22-27	Term	$1 \leq X \leq 72$ (months)
28-33	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
34-39	Term	$1 \leq X \leq 72$ (months)
40-45	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
46-51	Term	$1 \leq X \leq 72$ (months)
52-57	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$
58-63	Term	$1 \leq X \leq 72$ (months)
64-69	Corresponding proportion for term above	$0.0001 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This card type is analogous to card type 14 but applies to reenlistment terms of career airmen. Notice that the proportions must be greater than zero.

(3) The user may input multiple cards of this type to specify the distribution if more than five reenlistment terms must be simulated.

(4) This specification applies only to career airmen with less than 20 years in service. Career airmen with over 20 years are assumed to reenlist for 1 year.

Exhibit 17

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 16 — I/O: INPUT

DATA IDENTIFICATION: MINIMUM OBLIGATION UPON PROMOTION CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$1 \leq X \leq 360$ (months)
5-6	Card identification	Literal "16"
10-15	Obligation upon promotion to E9	$0 \leq X \leq 360$ (months)
16-21	Obligation upon promotion to E8	$0 \leq X \leq 360$ (months)
22-27	Obligation upon promotion to E7	$0 \leq X \leq 360$ (months)
28-33	Obligation upon promotion to E6	$0 \leq X \leq 360$ (months)
34-39	Obligation upon promotion to E5	$0 \leq X \leq 360$ (months)
40-45	Obligation upon promotion to E4	$0 \leq X \leq 360$ (months)
46-51	Obligation upon promotion to E3	$0 \leq X \leq 360$ (months)

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The numbers entered in columns 10-51 represent the minimum number of months an airman is obligated to serve upon obtaining the specified grade.

Exhibit 18

FORMAT SPECIFICATION

SYSTEM: CAROM | DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 17 | I/O: INPUT

DATA IDENTIFICATION: RETENTION RATE CARD | Page 1 of 3

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "17"
8	Sub-classification	Literal "0"
10-15	Retention rate for service time 0 to 1 years	$0.0 \leq X \leq 1.0$
16-21	Retention rate for service time 1 to 2 years	$0.0 \leq X \leq 1.0$
22-27	Retention rate for service time 2 to 3 years	$0.0 \leq X \leq 1.0$
28-33	Retention rate for service time 3 to 4 years	$0.0 \leq X \leq 1.0$
34-39	Retention rate for service time 4 to 5 years	$0.0 \leq X \leq 1.0$
40-45	Retention rate for service time 5 to 6 years	$0.0 \leq X \leq 1.0$
46-51	Retention rate for service time 6 to 7 years	$0.0 \leq X \leq 1.0$
52-57	Retention rate for service time 7 to 8 years	$0.0 \leq X \leq 1.0$
58-63	Retention rate for service time 8 to 9 years	$0.0 \leq X \leq 1.0$
64-69	Retention rate for service time 9 to 10 years	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

Exhibit 18

FORMAT SPECIFICATION

SYSTEM: CAROM
DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 17
I/O: INPUT

DATA IDENTIFICATION: RETENTION RATE CARD

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "17"
8	Sub-classification	Literal "1"
10-15	Retention rate for service time 10 to 11 years	$0.0 \leq X \leq 1.0$
16-21	Retention rate for service time 11 to 12 years	$0.0 \leq X \leq 1.0$
22-27	Retention rate for service time 12 to 13 years	$0.0 \leq X \leq 1.0$
28-33	Retention rate for service time 13 to 14 years	$0.0 \leq X \leq 1.0$
34-39	Retention rate for service time 14 to 15 years	$0.0 \leq X \leq 1.0$
40-45	Retention rate for service time 15 to 16 years	$0.0 \leq X \leq 1.0$
46-51	Retention rate for service time 16 to 17 years	$0.0 \leq X \leq 1.0$
52-57	Retention rate for service time 17 to 18 years	$0.0 \leq X \leq 1.0$
58-63	Retention rate for service time 18 to 19 years	$0.0 \leq X \leq 1.0$
64-69	Retention rate for service time 19 to 20 years	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

Exhibit 18

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 17 — I/O: INPUT

DATA IDENTIFICATION: RETENTION RATE CARD — Page 3 of 3

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "17"
8	Sub-classification	Literal "2"
10-15	Retention rate for service time 20 to 21 years	$0.0 \leq X \leq 1.0$
16-21	Retention rate for service time 21 to 22 years	$0.0 \leq X \leq 1.0$
22-27	Retention rate for service time 22 to 23 years	$0.0 \leq X \leq 1.0$
28-33	Retention rate for service time 23 to 24 years	$0.0 \leq X \leq 1.0$
34-39	Retention rate for service time 24 to 25 years	$0.0 \leq X \leq 1.0$
40-45	Retention rate for service time 25 to 26 years	$0.0 \leq X \leq 1.0$
46-51	Retention rate for service time 26 to 27 years	$0.0 \leq X \leq 1.0$
52-57	Retention rate for service time 27 to 28 years	$0.0 \leq X \leq 1.0$
58-63	Retention rate for service time 28 to 29 years	$0.0 \leq X \leq 1.0$
64-69	Retention rate for service time 29 to 30 years	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This distribution of retention rates is used both for reenlistment of airmen with less service time than 20 years and for airmen eligible for retirement from 20 to 30 years. Notice that 3 cards of this card type are required for a complete specification of the rates.

(3) For computational reasons, the model applies in the twelfth month of each service year the rate specified for the next service year. Thus, the rate specified for service time 0 to 1 year is actually applied by the model for service time 0 to 11 months, the rate for 1 to 2 years is applied for service time 12 to 23 months, etc., and the rate for 29 years and 11 months is automatically set to zero.

Exhibit 19

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 18 — I/O: INPUT

DATA IDENTIFICATION: UP OR OUT POLICY CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "18"
10-15	Maximum time in service allowed for grade E8	$0 \leq X \leq 360$ (months)
16-21	Maximum time in service allowed for grade E7	$0 \leq X \leq 360$ (months)
22-27	Maximum time in service allowed for grade E6	$0 \leq X \leq 360$ (months)
28-33	Maximum time in service allowed for grade E5	$0 \leq X \leq 360$ (months)
34-39	Maximum time in service allowed for grade E4	$0 \leq X \leq 360$ (months)
40-45	Maximum time in service allowed for grade E3	$0 \leq X \leq 360$ (months)
46-51	Maximum time in service allowed for grade E1/E2	$0 \leq X \leq 360$ (months)

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) The numbers entered in columns 10-51 represent the maximum number of months in service an airman in the specified grade is allowed before being forced to attrit upon completion of enlistment obligation.

Exhibit 20

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 19 — I/O: INPUT

DATA IDENTIFICATION: AUTHORIZED STRENGTH CARD — Page 1 of 2

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "19"
8	Tour identification	R, S, A or C
10-15	Proportion of E9 or Skill Level 9 billets in tour	$0.0 \leq X \leq 1.0$
16-21	Proportion of E8 or Skill Level 8 billets in tour	$0.0 \leq X \leq 1.0$
22-27	Proportion of E7 or Skill Level 7 billets in tour	$0.0 \leq X \leq 1.0$
28-33	Proportion of E6 or Skill Level 6 billets in tour	$0.0 \leq X \leq 1.0$
34-39	Proportion of E5 or Skill Level 5 billets in tour	$0.0 \leq X \leq 1.0$
40-45	Proportion of E4 or Skill Level 4 billets in tour	$0.0 \leq X \leq 1.0$
46-51	Proportion of E3 or Skill Level 3 billets in tour	$0.0 \leq X \leq 1.0$
52-57	Proportion of E1/E2 or Skill Level 1/Skill Level 2 billets in tour	$0.0 \leq X \leq 1.0$ $0.0 \leq X \leq 1.0$
58-63	Proportion of total authorized strength this tour	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This format applies to a grade or skill level only type of run. If the type of run has been specified as "B" and thus involves both grades and skill levels, use the alternate format specified on the next page.

(3) This card type requires one card for each tour.

Exhibit 20

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 19 — I/O: INPUT

DATA IDENTIFICATION: AUTHORIZED STRENGTH CARD — Page 2 of 2

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "19"
8	Tour identification	R, S, A or C
9	Skill level	$2 \leq X \leq 9$
10-15	Proportion of E9 billets in tour/skill level	$0.0 \leq X \leq 1.0$
16-21	Proportion of E8 billets in tour/skill level	$0.0 \leq X \leq 1.0$
22-27	Proportion of E7 billets in tour/skill level	$0.0 \leq X \leq 1.0$
28-33	Proportion of E6 billets in tour/skill level	$0.0 \leq X \leq 1.0$
34-39	Proportion of E5 billets in tour/skill level	$0.0 \leq X \leq 1.0$
40-45	Proportion of E4 billets in tour/skill level	$0.0 \leq X \leq 1.0$
46-51	Proportion of E3 billets in tour/skill level	$0.0 \leq X \leq 1.0$
52-57	Proportion of E1/E2 billets in tour/skill level	$0.0 \leq X \leq 1.0$
58-63	Proportion of total authorized strength this tour/skill level represents	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This format applies to a type "B" run. If the run involves grades only ("G") of skill levels only ("S"), use the alternate format specified on the previous page.

(3) This card type requires one card for each tour/skill level combination.

Exhibit 21

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 20 — I/O: INPUT

DATA IDENTIFICATION: TOUR LENGTH DISTRIBUTION CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "20"
8	Tour identification	R, S, A or C
9	First termer/careerist identification	F or C
10-15	Tour Length	$1 \leq X \leq 360$ (months)
16-21	Corresponding proportion for tour length above	$0.0001 \leq X \leq 1.0$
22-27	Tour length	$1 \leq X \leq 360$ (months)
28-33	Corresponding proportion for tour length above	$0.0001 \leq X \leq 1.0$
34-39	Tour length	$1 \leq X \leq 360$ (months)
40-45	Corresponding proportion for tour length above	$0.0001 \leq X \leq 1.0$
46-51	Tour length	$1 \leq X \leq 360$ (months)
52-57	Corresponding proportion for tour length above	$0.0001 \leq X \leq 1.0$
58-63	Tour length	$1 \leq X \leq 360$ (months)
64-69	Corresponding proportion for tour length above	$0.0001 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) Only one card is allowed for each tour category and personnel category (first termer/career airmen). Thus, only 5 discrete tour lengths may be specified per tour category/personnel category.

(3) Notice that the proportion associated with each specific tour length must be greater than zero.

(4) The tour length specification for CONUS applies only to the so called stabilized positions. A proportion (see card type 8) of airmen assigned to CONUS receive these fixed tour lengths, while the remainder does not have a fixed tour length and is subject only to minimum and maximum CONUS times.

Exhibit 22

FORMAT SPECIFICATION

SYSTEM: CAROM | DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 21 | I/O: INPUT

DATA IDENTIFICATION: ASSIGNMENT ELIGIBILITY CARD | Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "21"
8	Tour identification	R, S or A
10-15	Minimum time since last remote tour to tour in column 8	$0 \leq X \leq 360$ (months)
16-21	Minimum time since last special tour to tour in column 8	$0 \leq X \leq 360$ (months)
22-27	Minimum time since last accompanied tour to tour in column 8	$0 \leq X \leq 360$ (months)
28-33	Minimum remaining obligation for first termers to be eligible for tour	$0 \leq X \leq 360$ (months)
34-39	Maximum number of tours for careerists	$0 \leq X \leq 15$
40-45	Maximum number of tours for first termers	$0 \leq X \leq 15$
46-51	Maximum time to ETS for first termers to be ineligible for transfer from tour	$0 \leq X \leq 360$ (months)
52-57	Maximum time to ETS for careerists to be ineligible for transfer from tour	$0 \leq X \leq 360$ (months)
58-63	Proportion of airmen normally eligible for reassignment who are ineligible for special reasons	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) One card must be submitted for each non-CONUS tour category.

(3) All information on each card corresponds to the tour identified in card column 8.

(4) Notice that the minimum time to ETS in order to be eligible for tour applies only to first termers and not to career airmen.

Exhibit 23

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 22 — I/O: INPUT

DATA IDENTIFICATION: GENERAL EARLY OUT POLICY CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "22"
10-15	Maximum time to ETS for first termers to be eligible for early out	$0 \leq X \leq 360$ (months)
16-21	Proportion of remote eligibles who accept early out	$0.0 \leq X \leq 1.0$
22-27	Proportion of special eligibles who accept early out	$0.0 \leq X \leq 1.0$
28-33	Proportion of accompanied eligibles who accept early out	$0.0 \leq X \leq 1.0$
34-39	Proportion of CONUS eligibles who accept early out	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) Only first term airmen may be eligible for general early out. Thus, only one card of this card type is required.

Exhibit 24

FORMAT SPECIFICATION

SYSTEM: CAROM DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 23 I/O: INPUT

DATA IDENTIFICATION: TOUR COMPLETION EARLY OUT POLICY CARD Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "23"
8	First termer/careerist identification	F or C
10-15	Maximum time remaining upon completion of remote tour for early out	$0 \leq X \leq 360$ (months)
16-21	Proportion of remote eligible who accept early out	$0.0 \leq X \leq 1.0$
22-27	Maximum time remaining upon completion of special tour for early out	$0 \leq X \leq 360$ (months)
28-33	Proportion of special eligible who accept early out	$0.0 \leq X \leq 1.0$
34-39	Maximum time remaining upon completion of accompanied tour for early out	$0 \leq X \leq 360$ (months)
40-45	Proportion of accompanied eligible who accept early out	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) First termers and career airmen may have different tour completion early out policies. One card must be submitted for each airman category.

Exhibit 25

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 24 — I/O: INPUT

DATA IDENTIFICATION: DECORATION DISTRIBUTION CARD — Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$0 \leq X \leq 360$ (months)
5-6	Card identification	Literal "24"
8	Tour identification	R, S, A or C
10-15	Decoration score awarded	$0 \leq X \leq 25$
16-21	Corresponding proportion for score above	$0.0001 \leq X \leq 1.0$
22-27	Decoration score awarded	$0 \leq X \leq 25$
28-33	Corresponding proportion for score above	$0.0001 \leq X \leq 1.0$
34-39	Decoration score awarded	$0 \leq X \leq 25$
40-45	Corresponding proportion for score above	$0.0001 \leq X \leq 1.0$
46-51	Decoration score awarded	$0 \leq X \leq 25$
52-57	Corresponding proportion for score above	$0.0001 \leq X \leq 1.0$
58-63	Decoration score awarded	$0 \leq X \leq 25$
64-69	Corresponding proportion for score above	$0.0001 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) One card must be submitted for each tour category.

(3) The distribution of Decoration Scores awarded at tour completion is specified in terms of five different scores with the associated proportions. Notice that the proportions must be greater than zero.

Exhibit 26 A

FORMAT SPECIFICATION

SYSTEM: CAROM | DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 25 | I/O: INPUT

DATA IDENTIFICATION: PROMOTION STRENGTH CARD | Page 1 of 1

Card Column	Description	Comments
1-3	Simulation month	$1 \leq X \leq 360$ (months)
5-6	Card identification	Literal "25"
10-15	Proportion of promotion strength which have grade E9	$0.0 \leq X \leq 1.0$
16-21	Proportion of promotion strength which have grade E8 or higher	$0.0 \leq X \leq 1.0$
22-27	Proportion of promotion strength which have grade E7 or higher	$0.0 \leq X \leq 1.0$
28-33	Proportion of promotion strength which have grade E6 or higher	$0.0 \leq X \leq 1.0$
34-39	Proportion of promotion strength which have grade E5 or higher	$0.0 \leq X \leq 1.0$
40-45	Proportion of promotion strength which have grade E4 or higher	$0.0 \leq X \leq 1.0$
46-51	Proportion of promotion strength which have grade E3 or higher	$0.0 \leq X \leq 1.0$
52-57	Promotion strength	$0 \leq X \leq 999,999$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) Promotion strength = authorized strength + desired strength of next higher grade above the highest authorized grade in the career area. See footnote on page 32.

(3) Information from this card is utilized for the vacancy promotion quota system. Unlike card type 26, this card must always be present in the CAROM control deck. When card type 26 is present and the equal selection opportunity system is active, then information on this card is not utilized. See notes for card type 26.

Exhibit 26B

FORMAT SPECIFICATION

SYSTEM: CAROM
DATE: April 1973

RECORD/CARD TYPE: CARD TYPE 26
I/O: INPUT

DATA IDENTIFICATION: PROMOTION OPPORTUNITY CARD

Card Column	Description	Comments
1-3	Simulation month	$1 \leq X \leq 360$ (months)
5-6	Card identification	Literal "26"
10-15	Proportion of eligibles to be promoted to E9	$0.0 \leq X \leq 1.0$
16-21	Proportion of eligibles to be promoted to E8	$0.0 \leq X \leq 1.0$
22-27	Proportion of eligibles to be promoted to E7	$0.0 \leq X \leq 1.0$
28-33	Proportion of eligibles to be promoted to E6	$0.0 \leq X \leq 1.0$
34-39	Proportion of eligibles to be promoted to E5	$0.0 \leq X \leq 1.0$
40-45	Proportion of eligibles to be promoted to E4	$0.0 \leq X \leq 1.0$
46-51	Proportion of eligibles to be promoted to E3	$0.0 \leq X \leq 1.0$

NOTES: (1) Columns/character positions not referenced are irrelevant and left blank or may be used for user comments/identification purposes.

(2) This card is optional. When it is present in the CAROM control card deck, the equal selection opportunity promotion quota system as defined by the proportions on this card becomes active in the month specified in card columns 1-3. When this card is not present, the vacancy promotion quota system is active.

MONTHLY SUMMARY REPORT

TOUR CATEGORY	PER CENT OF TOTAL SPACES FILLED	PER CENT FILLED FROM GRADES ABOVE	PER CENT FILLED FROM GRADES BELOW	ASSIGNMENTS TO TOUR	ASSIGNMENTS FROM TOUR	OVERAGE (NEG, IF SHORAGE)	LOSSES FROM TOUR	TOTAL CAREER AREA	
								SIMULATION MONTH	0
REMOTE	100.0	14.9	11.2	720	50	0	0	ACTUAL STRENGTH ...	10564
SPECIAL	100.0	0.0	20.0	116	27	0	0	AUTHORIZED STRENGTH	10087
ACCOMPANIED	100.0	0.0	9.7	874	176	0	0	ACCESSIONS	10564
CONUS	100.0	3.0	38.5	253	1710	477	0	PROMOTIONS	0
TOTAL				1963	1963	477	0		
								SIMULATION MONTH	1
REMOTE	99.2	20.9	7.2	53	20	0	13	ACTUAL STRENGTH ...	10579
SPECIAL	98.5	0.0	11.6	37	28	0	9	AUTHORIZED STRENGTH	10087
ACCOMPANIED	98.1	5.3	2.4	74	46	0	28	ACCESSIONS	150
CONUS	94.8	0.0	12.0	83	133	492	85	PROMOTIONS	1875
TOTAL				227	227	492	135		
								SIMULATION MONTH	2
REMOTE	98.0	22.2	7.4	23	24	-15	14	ACTUAL STRENGTH ...	10569
SPECIAL	98.5	0.0	28.4	55	45	0	10	AUTHORIZED STRENGTH	10087
ACCOMPANIED	98.1	4.3	3.5	56	25	0	31	ACCESSIONS	150
CONUS	96.3	0.0	9.8	55	95	497	105	PROMOTIONS	383
TOTAL				189	189	482	160		
								SIMULATION MONTH	3
REMOTE	96.5	23.3	7.6	6	11	-32	12	ACTUAL STRENGTH ...	10589
SPECIAL	98.5	0.0	30.3	26	19	0	7	AUTHORIZED STRENGTH	10087
ACCOMPANIED	98.1	3.2	7.9	66	34	0	32	ACCESSIONS	150
CONUS	98.2	0.0	11.8	35	69	534	79	PROMOTIONS	350
TOTAL				133	133	502	130		
								SIMULATION MONTH	4
REMOTE	96.2	23.3	8.4	27	23	-36	8	ACTUAL STRENGTH ...	10606
SPECIAL	98.3	0.0	30.3	22	10	0	12	AUTHORIZED STRENGTH	10087
ACCOMPANIED	96.2	3.6	7.0	20	37	-45	28	ACCESSIONS	150
CONUS	100.0	0.0	14.0	20	19	600	85	PROMOTIONS	512
TOTAL				89	89	519	133		
								SIMULATION MONTH	5
REMOTE	99.9	20.5	13.5	67	18	0	13	ACTUAL STRENGTH ...	10621
SPECIAL	97.9	0.0	31.5	45	35	-2	12	AUTHORIZED STRENGTH	10087
ACCOMPANIED	94.0	4.1	5.6	32	59	-99	27	ACCESSIONS	150
CONUS	100.0	0.0	14.3	39	71	635	83	PROMOTIONS	456
TOTAL				183	183	534	135		

MONTHLY SUMMARY REPORT

TOUR CATEGORY	PER CENT OF TOTAL SPACES FILLED	PER CENT FILLED FROM SKILLS ABOVE	PER CENT FILLED FROM SKILLS BELOW	ASSIGNMENTS TO TOUR	ASSIGNMENTS FROM TOUR	OVERAGE (NEG. IF SHORAGE)	LOSSES FROM TOUR	TOTAL CAREER AREA
								SIMULATION MONTH 6
REMOTE	89.1	24.3	1.2	4	31	-46	19	ACTUAL STRENGTH ... 10597
SPECIAL	97.1	.2	24.4	56	46	-5	13	AUTHORIZED STRENGTH 10087
ACCOMPANIED	92.3	3.4	6.1	82	81	-139	41	ACCESSIONS 150
CONUS	100.0	0.0	12.0	49	33	700	101	PROMOTIONS 422
TOTAL				191	191	510	174	
								SIMULATION MONTH 7
REMOTE	86.7	24.1	2.1	1	19	-78	14	ACTUAL STRENGTH ... 10511
SPECIAL	89.2	.5	20.2	27	59	-56	19	AUTHORIZED STRENGTH 10087
ACCOMPANIED	91.6	3.0	6.4	62	45	-157	35	ACCESSIONS 150
CONUS	100.0	0.0	11.1	41	8	715	166	PROMOTIONS 446
TOTAL				131	131	424	236	
								SIMULATION MONTH 8
REMOTE	89.6	23.7	7.5	8	22	-100	8	ACTUAL STRENGTH ... 10449
SPECIAL	77.8	1.9	6.2	11	53	-104	6	AUTHORIZED STRENGTH 10087
ACCOMPANIED	90.9	5.6	3.6	54	26	-158	29	ACCESSIONS 150
CONUS	100.0	0.0	9.6	35	7	724	169	PROMOTIONS 569
TOTAL				108	108	362	212	
								SIMULATION MONTH 9
REMOTE	85.9	23.3	7.4	1	25	-136	12	ACTUAL STRENGTH ... 10396
SPECIAL	72.1	3.1	3.2	13	35	-135	9	AUTHORIZED STRENGTH 10087
ACCOMPANIED	95.3	2.5	6.6	131	19	-71	25	ACCESSIONS 150
CONUS	100.0	0.0	12.0	22	88	651	157	PROMOTIONS 338
TOTAL				167	167	309	203	
								SIMULATION MONTH 10
REMOTE	83.6	23.9	6.5	0	8	-158	14	ACTUAL STRENGTH ... 10314
SPECIAL	73.5	1.9	5.5	19	28	-150	6	AUTHORIZED STRENGTH 10087
ACCOMPANIED	95.9	1.8	8.2	58	15	-56	28	ACCESSIONS 150
CONUS	98.9	0.0	12.1	18	44	591	184	PROMOTIONS 418
TOTAL				95	95	227	232	
								SIMULATION MONTH 11
REMOTE	76.2	28.7	.7	0	12	-181	11	ACTUAL STRENGTH ... 10308
SPECIAL	70.6	2.6	3.4	10	19	-167	8	AUTHORIZED STRENGTH 10087
ACCOMPANIED	96.1	3.7	8.5	38	13	-53	22	ACCESSIONS 150
CONUS	100.0	0.0	11.3	18	22	622	115	PROMOTIONS 616
TOTAL				66	66	221	156	

MANNING LEVEL REPORT SIMULATION TIME PERIOD 1

TOUR CATEGORY	GRADE E9	GRADE E8	GRADE E7	GRADE E6	GRADE E5	GRADE E4	GRADE E3	GRADE E1/E2	TOTAL BY TOUR
REMOTE TOUR									
ACTUAL	0	2	87	224	333	224	25	74	969
AUTHORIZED	0	0	51	161	269	397	91	0	969
OVERAGE (- IF SHORTAGE)	0	2	36	63	64	-173	-66	74	0
PER CENT FILLED FROM GRADES BELOW	0.0	0.0	0.0	0.0	0.0	.5	74.7	0.0	
PER CENT FILLED FROM GRADES ABOVE	0.0	0.0	0.0	22.4	0.0	42.1	0.0	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	100.0	98.6	99.3	99.0	100.0	0.0	
SPECIAL TOUR									
ACTUAL	0	9	87	100	160	149	30	50	585
AUTHORIZED	0	0	89	112	158	145	81	0	585
OVERAGE (- IF SHORTAGE)	0	9	-2	-12	2	4	-51	50	0
PER CENT FILLED FROM GRADES BELOW	0.0	0.0	1.1	9.8	3.8	0.0	61.7	0.0	
PER CENT FILLED FROM GRADES ABOVE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	98.9	98.2	98.1	98.6	98.8	0.0	
ACCOMPANIED TOUR									
ACTUAL	0	46	255	562	697	586	194	40	2380
AUTHORIZED	0	0	259	548	638	743	222	0	2380
OVERAGE (- IF SHORTAGE)	0	46	-4	14	59	-157	-28	40	0
PER CENT FILLED FROM GRADES BELOW	0.0	0.0	0.0	0.0	0.0	2.2	18.0	0.0	
PER CENT FILLED FROM GRADES ABOVE	0.0	0.0	0.0	.2	0.0	17.0	0.0	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	98.1	98.0	98.2	98.0	98.2	0.0	
CONUS TOUR									
ACTUAL	0	144	840	1132	1328	1837	736	628	6645
AUTHORIZED	0	0	890	1269	1459	1910	625	0	6153
OVERAGE (- IF SHORTAGE)	0	144	-50	-137	-131	-73	111	628	492
PER CENT FILLED FROM GRADES BELOW	0.0	0.0	.4	6.8	12.5	13.5	33.6	0.0	
PER CENT FILLED FROM GRADES ABOVE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	94.3	94.2	94.2	94.2	100.0	0.0	
TOTAL BY GRADE									
ACTUAL	0	201	1269	2018	2518	2796	985	792	10579
AUTHORIZED	0	0	1289	2090	2494	3195	1019	0	10087
OVERAGE (- IF SHORTAGE)	0	201	-20	-72	24	-399	-34	792	492

Exhibit 30

C A R O M — CAROM SIMULATION OF AFSC 732X0 NO.1 — DATE 73/02/19 — PAGE 57

MANNING LEVEL REPORT — SIMULATION TIME PERIOD 1

TOUR CATEGORY	SKILL 9	SKILL 8	SKILL 7	SKILL 6	SKILL 5	SKILL 4	SKILL 3	SKILL 1/2	TOTAL BY TOUR
REMOTE TOUR									
ACTUAL	0	0	248	0	608	0	113	0	969
AUTHORIZED	0	0	212	0	666	0	91	0	969
OVERAGE (- IF SHORTAGE)	0	0	36	0	-58	0	22	0	0
PER CENT FILLED FROM SKILLS BELOW	0.0	0.0	30.7	0.0	5.9	0.0	0.0	0.0	
PER CENT FILLED FROM SKILLS ABOVE	0.0	0.0	0.0	0.0	15.2	0.0	25.3	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	99.1	0.0	99.1	0.0	100.0	0.0	
SPECIAL TOUR									
ACTUAL	0	0	183	0	328	0	74	0	585
AUTHORIZED	0	0	201	0	303	0	81	0	585
OVERAGE (- IF SHORTAGE)	0	0	-18	0	25	0	-7	0	0
PER CENT FILLED FROM SKILLS BELOW	0.0	0.0	11.9	0.0	1.0	0.0	0.0	0.0	
PER CENT FILLED FROM SKILLS ABOVE	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	98.5	0.0	98.3	0.0	98.8	0.0	
ACCOMPANIED TOUR									
ACTUAL	0	0	780	0	1406	0	194	0	2380
AUTHORIZED	0	0	807	0	1351	0	222	0	2380
OVERAGE (- IF SHORTAGE)	0	0	-27	0	55	0	-28	0	0
PER CENT FILLED FROM SKILLS BELOW	0.0	0.0	10.3	0.0	1.6	0.0	0.0	0.0	
PER CENT FILLED FROM SKILLS ABOVE	0.0	0.0	0.0	0.0	1.9	0.0	20.3	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	98.0	0.0	98.1	0.0	98.2	0.0	
CONUS TOUR									
ACTUAL	0	0	2018	0	3670	0	957	0	6645
AUTHORIZED	0	0	2159	0	3369	0	625	0	6153
OVERAGE (- IF SHORTAGE)	0	0	-141	0	301	0	332	0	492
PER CENT FILLED FROM SKILLS BELOW	0.0	0.0	8.3	0.0	9.3	0.0	0.0	0.0	
PER CENT FILLED FROM SKILLS ABOVE	0.0	0.0	0.0	0.0	0.0	0.0	66.4	0.0	
PER CENT TOTAL SPACES FILLED	0.0	0.0	94.3	0.0	94.2	0.0	100.0	0.0	
TOTAL BY SKILL									
ACTUAL	0	0	3229	0	6012	0	1338	0	10579
AUTHORIZED	0	0	3379	0	5689	0	1019	0	10087
OVERAGE (- IF SHORTAGE)	0	0	-150	0	323	0	319	0	492

ASSIGNMENT, LOSS AND PROMOTION REPORT SUMMARY FOR TIME PERIODS 1 TO 1

NUMBER OF NEW ACCESSIONS 150

TOUR CATEGORY	GRADE E9	GRADE E8	GRADE E7	GRADE E6	GRADE E5	GRADE E4	GRADE E3	GRADE E1/E2	TOTAL BY TOUR
REMOTE TOUR									
ASSIGNMENTS MOVES TO	0	0	35	174	311	145	17	71	753
TRANSFER FROM	0	0	7	9	18	36	0	0	70
LOSSES TOTAL	0	0	0	5	2	4	0	2	13
NON-REENLISTMENT	0	0	0	1	0	0	0	0	1
EXCEPTIONAL ATTRITION	0	0	0	4	2	4	0	2	12
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	0	0	0	0	0	0	0
SPECIAL TOUR									
ASSIGNMENTS MOVES TO	0	0	44	28	9	0	17	55	153
TRANSFER FROM	0	2	3	13	18	19	0	0	55
LOSSES TOTAL	0	0	4	1	1	2	0	1	9
NON-REENLISTMENT	0	0	0	0	0	0	0	0	0
EXCEPTIONAL ATTRITION	0	0	4	1	1	2	0	1	9
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	0	0	0	0	0	0	0
ACCOMPANIED TOUR									
ASSIGNMENTS MOVES TO	0	0	97	246	206	227	12	160	948
TRANSFER FROM	0	1	44	87	65	25	0	0	222
LOSSES TOTAL	0	0	5	5	3	11	2	2	28
NON-REENLISTMENT	0	0	0	0	0	1	0	0	1
EXCEPTIONAL ATTRITION	0	0	5	5	3	9	2	2	26
EARLY OUT	0	0	0	0	0	1	0	0	1
UP OR OUT	0	0	0	0	0	0	0	0	0
CONUS TOUR									
ASSIGNMENTS MOVES TO	0	3	51	101	101	80	0	0	336
TRANSFER FROM	0	0	173	440	526	372	46	286	1843
LOSSES TOTAL	0	0	12	24	8	24	8	9	85
NON-REENLISTMENT	0	0	2	11	0	2	0	0	15
EXCEPTIONAL ATTRITION	0	0	8	12	8	22	7	9	66
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	2	1	0	0	1	0	4
DUE TO CONUS OVERAGE	0	0	0	0	0	0	0	0	0
TOTAL BY GRADE									
ASSIGNMENTS MOVES TO	0	3	227	549	627	452	46	286	2190
TRANSFER FROM	0	3	227	549	627	452	46	286	2190
LOSSES TOTAL	0	0	21	35	14	41	10	14	135
NON-REENLISTMENT	0	0	2	12	0	3	0	0	17
EXCEPTIONAL ATTRITION	0	0	17	22	14	37	9	14	113
EARLY OUT	0	0	0	0	0	1	0	0	1
UP OR OUT	0	0	2	1	0	0	1	0	4
DUE TO CONUS OVERAGE	0	0	0	0	0	0	0	0	0
PROMOTION SUMMARY *******									
TOTAL	0	0	201	288	259	704	270	153	1875

ASSIGNMENT, LOSS AND PROMOTION REPORT SUMMARY FOR TIME PERIODS 1 TO 1

NUMBER OF NEW ACCESSIONS 150

TOUR CATEGORY	SKILL 9	SKILL 8	SKILL 7	SKILL 6	SKILL 5	SKILL 4	SKILL 3	SKILL 1/2	TOTAL BY TOUR
REMOTE TOUR									
ASSIGNMENTS MOVES TO	0	0	209	0	384	0	160	0	753
TRANSFER FROM	0	0	13	0	57	0	0	0	70
LOSSES TOTAL	0	0	5	0	5	0	3	0	13
NON-REENLISTMENT	0	0	1	0	0	0	0	0	1
EXCEPTIONAL ATTRITION	0	0	4	0	5	0	3	0	12
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	0	0	0	0	0	0	0
SPECIAL TOUR									
ASSIGNMENTS MOVES TO	0	0	70	0	11	0	72	0	153
TRANSFER FROM	0	0	17	0	38	0	0	0	55
LOSSES TOTAL	0	0	5	0	3	0	1	0	9
NON-REENLISTMENT	0	0	0	0	0	0	0	0	0
EXCEPTIONAL ATTRITION	0	0	5	0	3	0	1	0	9
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	0	0	0	0	0	0	0
ACCOMPANIED TOUR									
ASSIGNMENTS MOVES TO	0	0	343	0	439	0	166	0	948
TRANSFER FROM	0	0	129	0	93	0	0	0	222
LOSSES TOTAL	0	0	10	0	14	0	4	0	28
NON-REENLISTMENT	0	0	0	0	1	0	0	0	1
EXCEPTIONAL ATTRITION	0	0	10	0	12	0	4	0	26
EARLY OUT	0	0	0	0	1	0	0	0	1
UP OR OUT	0	0	0	0	0	0	0	0	0
CONUS TOUR									
ASSIGNMENTS MOVES TO	0	0	150	0	186	0	0	0	336
TRANSFER FROM	0	0	613	0	832	0	398	0	1843
LOSSES TOTAL	0	0	36	0	34	0	15	0	85
NON-REENLISTMENT	0	0	13	0	2	0	0	0	15
EXCEPTIONAL ATTRITION	0	0	20	0	31	0	15	0	66
EARLY OUT	0	0	0	0	0	0	0	0	0
UP OR OUT	0	0	3	0	1	0	0	0	4
CONUS OVERAGE	0	0	0	0	0	0	0	0	0
TOTAL BY SKILL									
ASSIGNMENTS MOVES TO	0	0	772	0	1020	0	398	0	2190
TRANSFER FROM	0	0	772	0	1020	0	398	0	2190
LOSSES TOTAL	0	0	56	0	56	0	23	0	135
NON-REENLISTMENT	0	0	14	0	3	0	0	0	17
EXCEPTIONAL ATTRITION	0	0	39	0	51	0	23	0	113
EARLY OUT	0	0	0	0	1	0	0	0	1
UP OR OUT	0	0	3	0	1	0	0	0	4
DUE TO CONUS OVERAGE	0	0	0	0	0	0	0	0	0
PROMOTION SUMMARY *******									
TOTAL	0	0	0	0	0	0	551	0	551

Exhibit 33

FORMAT SPECIFICATION

SYSTEM: CAROM — DATE: April 1973

RECORD/CARD TYPE: PERSONNEL DATA RECORD — I/O: OUTPUT

DATA IDENTIFICATION: LOSS FILE AND PERSONNEL STATUS FILE — Page 1 of 1

Card Column	Description	Comments
1-4	Time in service	In months, at time of drop (see 68-70)
5-7	ETS	In month of simulation
8-11	Time in grade	In months
12	First term/careerist flag	0 or 1: first termer; 2 or 3 careerist
13-15	Tour completion date	Current tour at time of drop
16-17	Number of remote tours	Previous as well as present
18-21	Tour completion date of last remote tour	
22-23	Number of special tours	Previous as well as present
24-27	Tour completion date of last special tour	
28-29	Number of accompanied overseas tours	Previous as well as present
30-33	Tour completion date of last accompanied tour	
34	Loss flag	0 = in terminal inventory; 1 = up-or-out loss 2 = ETS loss 3 = exceptional loss 4 = general early-out 5 = tour completion early-out 6 = CONUS excess loss
35-36	Tour history	Integer between 1-16 identifying past & present tour R = 1, S = 2, A = 3, C = 4 Integer = (past tour -1) X4 + present tour
37-39	Exceptional attrition date	Equals time of drop if loss flag = 3
40	Skill level	
41	Grade	
42-45	Date of skill level	If date < time of drop: date of current skill level If date > time of drop: date of next higher skill
46-47	SKT score	
48-50	PFE score	
51-52	APR score	
53-54	Decorations score	
55-57	Unspecified factor 1 score	
58-60	Unspecified factor 2 score	
68-70	Month of drop	If not dropped (loss flag = 0), this is the final simulation month.

Exhibit 34
SCOPE CONTROL CARD DECK

```
$SEQUENCE, XXX.
$CHARGE,XXXXXXX-XXX.
USAF(PX, TXXX, TP2, CMXXXXXX)
REQUEST, CAROM. (XXXX/NORING)
REQUEST, TAPE9, S. (XXXX/NORING)
CAROM.
REWIND (TAPE4)
REWIND (TAPE8)
COPYCF(TAPE8,OUTPUT)
COPYCF(TAPE4,OUTPUT)
7
8
9
```

CAROM Control Card Deck (user prepared)

```
6
7
8
9
```

NOTES

(1) If the user wants to analyze the personnel data records on the Loss File and Personnel Status File, he must instruct the system to dump these records onto tape 7 to be saved for later processing. Add the following card after the two REQUEST cards above: REQUEST,TAPE7. (SAVE)

(2) If the user wants to save the reports on tape in addition to the hard copy reports, the following changes have to be made:

(a) Change in the JOB CARD TP2 to TP4.
(b) Add 2 additional REQUEST CARDS as follows: REQUEST, TAPE4.(SAVE)
REQUEST,TAPE8. (SAVE)

Tape 4 contains the optional reports and tape 8 the card listing, error messages and the monthly summary reports.

(3) The JOB card parameters determine run cost and memory allocated to run:
PX = job priority which determines the turnaround time and the computer charge per system second: X = 0 - economy (weekend) $0.20; X = 2 - deferred (24 hours) $0.24; X = 4 - standard (4 hours) $0.28; X = 6 - express (2 hours) $0.33.
TXXX = Central Processor time limit in octal. For time estimation see text.
CMXXXXXX = Central Memory reserved for job in octal. This parameter should agree with the field length specified in CAROM card type 01 (see Chapter IV,A,2,a).

Exhibit 35

C A R O M — INPUT FOR TIME PERIOD 0 — PAGE 1

```
RUN PARAMETER CARD                    000 01 B CAROM SIMULATION OF AFSC 732X0 NO,1 730219     60  1  1 XXXX 145000
GRADE/SKILL COMBINATIONS CARD         000 02          357   7 7   7 7   7 7   5 7   5 5   3 5   3 5   3 3
TOUR SEQUENCE DESIRABILITY CARD       000 03 R            C           D           B         E  A
                                      000 03 S            C           D           B         E  A
                                      000 03 A            C           B           D  F  E      A
                                      000 03 C       F          E     C  A        D  B  G  H
GRADE/SKILL LEVEL SUBSTITUTION CARD   000 04 33 35 23 45 55
                                      000 04 45 43 33 55 67 65
                                      000 04 55 45 43 33 67 65
                                      000 04 67 65 55 45 77
                                      000 04 77 67 65 55 45
LEVEL DEFINITION CARD                 000 05A33AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEEFAFBFCFDFE
                                      000 05A45AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEEFAFBFCFDFE
                                      000 05A55AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEEFAFBFCFDFE
                                      000 05A67AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEEFAFBFCFDFE
                                      000 05A77AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEEFAFBFCFDFE
                                      000 05C33AAABACADBABBBCBDCACBCCCDDADBDCDDEAEBECEDFAFBFCFDGAGBGCGDHAHBHCHD
                                      000 05C45AAABACADBABBBCBDCACBCCCDDADBDCDDEAEBECEDFAFBFCFDGAGBGCGBHAHBHCHD
                                      000 05C55AAABACADBABBBCBDCACBCCCDDADBDCDDEAEBECEDFAFBFCFDGAGBGCGDHAHBHCHD
                                      000 05C67AAABACADBABBBCBDCACBCCCDDADBDCDDEAEBECEDFAFBFCFDGAGBGCGDHAHBHCHD
                                      000 05C77AAABACADBABBBCBDCACBCCCDDADBDCDDEAEBECEDFAFBFCFDGAGBGCGDHAHBHCHD
                                      000 05R33AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
                                      000 05R45AAABACADAEAFBABBBCBDBEBFCACBCCCDCECFDADBDCDDDEDFEAEBECEDEEEF
                                      000 05R55AAABACADAEAFBABBBCBDBEBFCACBCCCDCECFDADBDCDDDEDCEAEBFCEDFEEF
                                      000 05R67AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
                                      000 05R77AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
                                      000 05S33AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
                                      000 05S45AAABACADAEAFBABBBCBDBEBFCACBCCCDCECFDADBDCDDDEDFEAEBFCEDFEEF
                                      000 05S55AAABACADAEAFBABBBCBDBEBFCACBCCCDCECFDADBDCDDDEDFEAEBECEDEEEF
                                      000 05S67AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
                                      000 05S77AAABACADAEBABBBCBDBECACBCCCDCEDADBDCDDDEEAEBECEDEE
SHARING POLICY AND PRIORITY CARD      000 06 23     1.    1.    1.    1.    2     1     3     4
                                      000 06 33     1.    1.    1.    1.    2     1     3     4
                                      000 06 35     1.    1.    1.    1.    2     1     3     4
                                      000 06 43     1.    1.    1.    1.    2     1     3     4
                                      000 06 45     1.    1.    1.    1.    2     1     3     4
                                      000 06 55     1.    1.    1.    1.    2     1     3     4
                                      000 06 65     1.    1.    1.    1.    2     1     3     4
                                      000 06 67     1.    1.    1.    1.    2     1     3     4
                                      000 06 77     1.    1.    1.    1.    2     1     3     4
                                      000 06 87     1.    1.    1.    1.    2     1     3     4
                                      000 06 97     1.    1.    1.    1.    2     1     3     4
WAPS UPDATING DATA CARD               000 07        12  11.0   8.0   4.2   0.0   0.0    25
MODEL PARAMETER AND ELIGIBILITY CARD  000 08   0100870000.01      0000000000120000120000120000120000,10000,11
MINIMUM TIME IN GRADE CARD            000 09       360    24    24    18    12     8     5
MINIMUM TIME IN SKILL LEVEL CARD      000 10       360   360     1    12     1     6     1
MINIMUM TIME IN SERVICE CARD          000 11       360   132    96    60    36    15     7
```

```
WEIGHTS OF TEST SCORES CARD          000 12 8 0.0   0.0   0.0   0.0   0.0   1.0   0.0   0.0
                                     000 12 7 0.0   0.0   0.0   0.0   0.0   1.0   0.0   0.0
                                     000 12 6 1.0   1.0   1.5   1.0   0.0   0.0   0.5   .167
                                     000 12 5 1.0   1.0   1.5   1.0   0.0   0.0   0.5   .167
                                     000 12 4 1.0   1.0   1.5   1.0   0.0   0.0   0.5   .167
                                     000 12 3 0.0   0.0   0.0   0.0   0.0   0.0   1.0   0.0
                                     000 12 2 0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.0
SKILL PROMOTION DISTRIBUTION CARD    000 13 3       0    1.0
                                     000 13 5       0    1.0
                                     000 13 7       0    1.0
FIRST TERMER REENLISTMENT DIST. CARD 000 14         48   1.0
CAREERIST REENLISTMENT DIST. CARD    000 15         48   1.0
MIN OBLIGATION UPON PROMOTION CARD   000 16         24    24    24     0     0     0     0
RENTENTION RATE CARD                 000 17 0  0.88  0.91  0.90  0.36  0.93  0.94  0.90  0.87  0.96  0.98
                                     000 17 1  0.98  0.98  0.90  0.98  0.99  0.98  0.99  0.99  0.99  0.48
                                     000 17 2  0.76  0.74  0.81  0.85  0.87  0.67  0.64  0.25  0.76  0.38
UP OR OUT CARD                       000 18     132   312   276   240   240    48    48
AUTHORIZED STRENGTH CARD             000 19 R3                                          1.0         0.009
                                     000 19 R5                          0.404 0.596               0.066
                                     000 19 R7                0.239 0.761                         0.021
                                     000 19 S3                                          1.0         0.008
                                     000 19 S5                          0.521 0.479               0.030
                                     000 19 S7                0.444 0.556                         0.020
                                     000 19 A3                                          1.0         0.022
                                     000 19 A5                          0.450 0.550               0.134
                                     000 19 A7                0.321 0.679                         0.080
                                     000 19 C3                                          1.0         0.062
                                     000 19 C5                          0.433 0.567               0.334
                                     000 19 C7                0.412 0.588                         0.214
TOUR LENGTH DISTRIBUTION CARD        000 20 CC48    .2    36    .8
                                     000 20 AC18    .05   24    .2    30    .2    36    .2    48    .35
                                     000 20 AF18    .5    24    .5
                                     000 20 CF1     1.0
                                     000 20 RF      12    1.0
                                     000 20 SF      12    1.0
                                     000 20 RC      12    1.0
                                     000 20 SC      12    1.0
ASSIGNMENT ELIGIBILITY CARD          000 21 R       12     12     12      9     15      1      5     5  0.05
                                     000 21 S       12     12     12      9     15      1      5     5  0.05
                                     000 21 A       12     12     12     18      5      1      5     5  0.05
GENERAL EARLY OUT POLICY CARD        000 22          0    0.0   0.0    0.0   0.0
TOUR COMPLETION EARLY OUT POLICY CARD 000 23 F      5    1.0     5     1.0     5    1.0
                                     000 23 C       5    1.0     5     1.0     5    1.0
DECORATION DISTRIBUTION CARD         000 24 A      00 0.914    03 0.083    05 0.003
                                     000 24 C      00 0.941    03 0.053    05 0.004    06 0.002
                                     000 24 R      00 0.957    03 0.043
                                     000 24 S      00 0.794    03 0.157    05 0.037    06 0.006    08 0.006
GRADE-AND-ABOVE CARD                 000 25   0.0   .0098 .0725 .1742 .2953 .4506 1.0   20578
```

Exhibit 36

CAROM SYSTEM DIAGNOSTICS

(CAROM ERROR MESSAGES)

1. --ERROR MESSAGE-- THE ABOVE DATA CATEGORY IS INCOMPLETE.

   This occurs when the user leaves out one or more cards in any card type which requires more cards than submitted.

2. --ERROR MESSAGE-- THERE ARE MORE THAN 28 LEGAL GRADE/SKILL COMBINATIONS DEFINED ON CARD TYPE 2.

   This occurs when the user specifies more than the maximum allowable 28 grade/skill level combinations in card type 2.

3. --ERROR MESSAGE-- THERE IS NO COMMON SKILL LEVEL BETWEEN GRADE E - AND GRADE E-

   This occurs when the user's card type 2 does not have a common skill level between the grades specified, which would make grade promotion impossible since the airman must have a legal grade/skill level combination upon promotion.

4. --ERROR MESSAGE--THE FIELDS WILL ALSO INCLUDE ILLEGAL GRADE/SKILL COMBINATIONS.

   This message occurs when an illegal grade/skill level combination is used in card type 4. This message is always accompanied by error message 9.

5. --ERROR MESSAGE-- THERE ARE TOO MANY PROMOTION TERMS FOR SKILL LEVEL ABOVE.

   This occurs when user tries to use more than two cards per skill level on card type 13, defining the time lapse between attainment of eligibility for and award of next higher skill level.

6. --ERROR MESSAGE-- THERE ARE TOO MANY TOUR LENGTHS FOR TOUR ABOVE.

   This occurs when user tries to use more than one card per tour on card type 20.

7. --ERROR MESSAGE-- THE ABOVE CARD HAS CARD ID WHICH IS ILLEGAL - CARD WILL NOT BE ERROR CHECKED.

   This occurs when the user has an illegal card ID.

8. --ERROR MESSAGE-- THE ABOVE CARD IS OUT OF ORDER - CARD WILL NOT BE ERROR CHECKED.

   This occurs when the card type and/or the simulation month specified in the card is such that the user is going back in time or card type sequence with request to the CARD READ earlier.

9. --ERROR MESSAGE-- THE ABOVE CARD (RECORD) HAS EITHER ILLEGAL CHARACTERS OR DATA WHICH IS OUT OF RANGE.

This means that the field in question does not fit within the limits stated for that field.

10. THERE IS NOT ENOUGH ROOM TO FIT FF IN CORE --STOP--

PROBLEM TOO BIG FOR QUOTFIND HAVE ONLY XXXX WORDS FOR XXXXX ROWS.

NUMBER OF ORIGINAL ROWS EXCEEDS LIMIT = XXXXXX.

Any of the above error messages will occur when the model was not given enough core to operate for the number of airman records input by the user.

Exhibit 37

CDC 6600 HOLLERITH CODES

Character	Display Code	External BCD	Hollerith Punch Positions
A	01	61	12-1
B	02	62	12-2
C	03	63	12-3
D	04	64	12-4
E	05	65	12-5
F	06	66	12-6
G	07	67	12-7
H	10	70	12-8
I	11	71	12-9
J	12	41	11-1
K	13	42	11-2
L	14	43	11-3
M	15	44	11-4
N	16	45	11-5
O	17	46	11-6
P	20	47	11-7
Q	21	50	11-8
R	22	51	11-9
S	23	22	0-2
T	24	23	0-3
U	25	24	0-4
V	26	25	0-5
W	27	26	0-6
X	30	27	0-7
Y	31	30	0-8
Z	32	31	0-9
0	33	12	0
1	34	01	1
2	35	02	2
3	36	03	3
4	37	04	4
5	40	05	5

CDC 6600 HOLLERITH CODES

Character	Display Code	External BCD	Hollerith Punch Positions
6	41	06	6
7	42	07	7
8	43	10	8
9	44	11	9
+	45	60	12
-	46	40	11
*	47	54	11-8-4
/	50	21	0-1
(	51	34	0-8-4
)	52	74	12-8-4
$	53	53	11-8-3
=	54	13	8-3
blank	55	20	space
,	56	33	0-8-3
.	57	73	12-8-3
≡	60	36	0-8-6
{	61	17	8-7
}	62	32	0-8-2
:	63	00	8-2
≠	64	14	8-4
→	65	35	0-8-5
v	66	52	11-0
^	67	37	0-8-7
↑	70	55	11-8-5
↓	71	56	11-8-6
<	72	72	12-0
>	73	57	11-8-7
≤	74	15	8-5
≥	75	75	12-8-5
¬	76	76	12-8-6

APPENDIX A

TECHNICAL DESCRIPTION OF THE CAROM ALLOCATOR ALGORITHMS

Description of the QUOTFIND algorithm

The QUOTFIND algorithm is designed to provide an optimal solution to the quota accommodation problem, i.e., the maximum possible fill of each quota such that a given shortage sharing policy is optimally adhered to. The solution consists of a set of feasible, reduced quotas, each reduced quota less than or equal to the corresponding original quota. These reduced quotas represent the optimal fills of the original quotas. In other words, the reduced quotas can all be met while the same number of men assignable under the original quotas are assignable under the reduced quotas. The process can be described as one of fitting the quotas to the available talent pool.

The shortage sharing or quota reduction policies can be specified in terms of two sets of constonts. The first set assigns each quota to a priority group. Priority groups are processed sequentially, with quotas in high priority groups being filled as much as possible prior to and at the expense of quotas in lower priority groups. The second set of constants are "share coefficients" which represent the weighting factor applied to the differential value associated with assigning a man to a particular quota. The exact mathematical formulations used are presented below. In general, if a given quota's share coefficient is large with respect to other share coefficients in its priority group, the ratio of the reduced quota to original quota will be larger than such ratios for the other quotas. If all quotas in the same priority group have identical share coefficients, they will tend to receive an identical per cent fill to the extent that such distribution is feasible.

QUOTFIND is an iterative model which assigns men, adjusts quotas, reassigns men, readjusts quotas, etc. The process terminates when the given sharing policies have been met as well as possible. QUOTFIND is composed of four major sections:

- A control section (QF),
- An assignment or reassignment process (MAXFLOW),
- A partitioning process (TRANSFER), and
- A quota adjustment process (FQF).

These routines are described next.

1. QF

To simplify the description of QF, let us assume for the time being that all quotas (columns) are in the same priority group, since multiple priorities complicate the procedure, as will be explained later. QF first calls MAXFLOW to assign as many men (rows) as possible without exceeding any original quota. If all quotas have been met, then processing terminates. Otherwise, upon return from MAXFLOW the columns are separated into labeled and unlabeled groups. All labeled columns have their quotas exactly met while vacancies exist in some unlabeled columns. No man who is not already assigned to an unlabeled column is eligible for one. Thus the quotas in these unlabeled columns must be reduced.

The group of unlabeled columns becomes the original set to be subjected to the so-called shredding process -- a recursive procedure consisting of the following operations. First, QF calls FQF to adjust the quotas on these columns so that the sum of the reduced quotas for the unlabeled columns equals the number of men currently assigned to those columns. Then QF calls TRANSFER to move a maximum number of men from categories with an excess to categories with a shortage (relative to the reduced quotas). If all reduced quotas are

exactly met, then processing terminates for this set of columns. Otherwise, the labels which TRANSFER sets become the means for partitioning the set of columns into two subsets:

— Subset (1) containing all columns which are labeled (i.e.,whose adjusted quotas are exceeded), and

— Subset (2) containing all columns which are unlabeled (i.e. whose adjusted quotas are not met.

Those columns whose adjusted quotas are exactly met are put in either one of the subsets based on the criterion that no man assigned to a column in subset (1) should be eligible for any column in subset (2) and vice-versa. The shredding process now continues with the columns in subset (2). FQF is called to adjust their quotas again such that the sum of the new reduced quotas within the subset equals the number of men assigned to the subset. TRANSFER again reassigns men within this subset and, if necessary, the shredding process continues until for a particular sub-subset the adjusted quotas are met. When a subset of type (2) has been processed completely, the complementary subset of type (1) is then processed in the same manner. Since there were a finite number of columns in the original set, processing is guaranteed to terminate with all adjusted quotas met. The quota adjustment is such that no adjusted quota ever exceeds the original quota.

Everything that has been discussed so far applies only to columns with equal priorities. The word "priority" implies a process in which every effort is made to fill a high priority quota before a lower priority quota is even considered. There is no attempt to share or distribute shortages over quotas of unequal priority. High priority quotas must be filled to the fullest extent possible before a single man enters a quota of lower priority. Sharing is an entirely different concept.

If there are enough men to fill all quotas to 75%, "fair-sharing" would fill each to 75% of its quota if possible. "Unfair-sharing" might fill an important quota to 90% and a less important one to only 60%, but it still attempts to distribute shortages according to some pattern rather than try to fill the important quotas 100% and the least important quotas 0%.

The program is written so that both the priority system and the sharing system can be used in conjunction with one another. At each stage, MAXFLOW and TRANSFER work with all the columns whose priorities exceed a certain threshold. At first only the highest priority columns are run. Then the threshold is lowered and the highest priority and second-highest priority categories are run with MAXFLOW or TRANSFER, and so forth. However, at the second stage, MAXFLOW starts with the assignments previously made to the highest priority quotas. A characteristic of the algorithm is that a man is never transferred out of a column unless a replacement is found for him. Thus, the number of men assigned to the highest priority quotas never diminishes.

After each call of MAXFLOW or TRANSFER, quota reduction and sharing is executed only on the columns whose priorities exactly equal the current value of the threshold. Columns of higher or lower priority than the threshold are ignored. Thus sharing is done only among quotas of equal priority.

2. MAXFLOW

The task of assigning men to a set of assignment categories with specified quotas and different eligibility requirements is accomplished by means of the MAXFLOW algorithm. A man may be eligible for any set of categories but may be assigned to only one of the categories for which he is eligible. MAXFLOW

takes advantage of these multiple eligibilities to assign the greatest number of men possible without exceeding quota limitations. MAXFLOW is an iterative algorithm incorporating a specialized version of the maximum flow algorithm developed by Ford and Fulkerson.

To begin with, MAXFLOW attempts to assign each man directly to an assignment category for which he is eligible and in which there is a vacancy. If at the end of this process all quotas have been filled or no unassigned man is eligible for any category, the assignment is complete. This is the trivial case of the assignment problem. In general, there will still remain unassigned men who are eligible only for categories which are already full, and there will be assigned men who are eligible for other unfilled categories. In this case MAXFLOW attempts to move men out of filled categories into unfilled ones in order to leave vacancies for men who are presently unassigned so as to maximize the number of assignments. A man is never moved into a category for which he is not eligible and he is never moved out of a category unless there is another man eligible to take his place. No man once assigned to any category will ever be returned to the unassigned pool.

To assist in the understanding of the MAXFLOW process, the concept of a chain is introduced. A chain is a sequence of the form: man_1, $category_2$ and man_2, $category_3$ and man_3, ..., $category_{n-1}$ and man_{n-1}, $category_n$; where

man_1 is unassigned

man_k is assigned to $category_k$, $k \geq 2$

man_k is also eligible for $category_{k+1}$, $k \geq 1$

$category_k$ is full, $k < n$

$category_n$ has a vacancy.

Man_1 is called the "origin" and $category_n$ is called the "terminus." The men and categories appearing in a chain are called links. No two links are identical.

At each iteration MAXFLOW identifies those categories which are the termini of chains of minimal length (or indicates that no chains exist). One chain is associated with each such terminus. A flow takes place along one of these chains, i.e., man_{n-1} is reassigned to $category_n$, man_{n-2} is reassigned to $category_{n-1}$,...., man_1 is assigned to $category_2$. The net effect of such a flow is to assign one more man. A flow occurs along each of the other minimal length chains as long as such a chain does not intersect one along which a flow has already been achieved. When all possible flows have been made, a new iteration is begun. It can be shown that when there are no chains left in the system, the assignment is complete, i.e., the maximum number has been assigned.

It would be extremely time consuming to trace through each possible chain in the system attempting to identify actual chains. Instead MAXFLOW identifies all men who constitute possible first links in chains, next, all categories which are possible third links, etc. MAXFLOW labels each possible link at the time that it is identified. Labeling is accomplished as follows:

- first, MAXFLOW labels unassigned men;
- next, it labels any category for which an unassigned man is eligible;
- then it labels any man who is assigned to a labeled category;
- next, it labels any unlabeled category for which a newly labeled man is eligible, etc.

A category is always labeled with the index of an eligible man. This process continues until either: (1) a category with a vacancy is labeled (in which case

MAXFLOW finishes the labeling of all categories on this pass, but does not label any more men); or (2) no more labeling is possible. In case (1), chain flows may take place as described above since $category_n$ is labeled with the index of man_{n-1}, who in turn is assigned to $category_{n-1}$, which is labeled with the index of man_{n-2}, etc. In case (2), the assignment is complete, which can be shown as follows: No labeled man is eligible for any unlabeled category (otherwise the category would be labeled). Thus, only unlabeled men are eligible for unlabeled categories. These unlabeled men are already assigned to unlabeled categories. Hence, as many men as possible are assigned to labeled categories. Therefore, the maximum number of men have been assigned.

Specifically, the labeling process and the flow process involve the following operations:

LABELING PROCESS*

Step 1: Clear all labels (men as well as assignment categories).

Step 2: All unassigned men are labeled.

Step 3: Any unlabeled category which has a labeled man eligible for it is labeled with the index of the man.

Step 4: If a category with a vacancy was labeled in Step 3, go to Step 6 to achieve a flow. If every labeled category is full, go to Step 5. If no category was labeled in Step 3, then the assignment is complete, so terminate.

Step 5: Clear all labeled men and label each man assigned to any category which was labeled in Step 3. Go to Step 3.

*In the labeling process used by DRNMLF, mentioned previously, step 1 is skipped and in step 2 either unassigned men or men assigned to a particular column may be used as an initial source. Furthermore, the exit to step 6 from step 4 is eliminated so that all possible labels are generated.

FLOW PROCESS

Step 6: A category with a vacancy has been labeled. Reduce its quota by one.

Step 7: Assign the man identified by the category label to the associated category, saving the previous assignment of that man. If the man was previously unassigned, return to Step 1 of the labeling process. Otherwise, proceed to Step 8.

Step 8: Obtain the label of the assignment category to which the man was previously assigned and go to Step 7.

Upon termination of MAXFLOW in Step 4, the set of categories is split into a labeled subset and an unlabeled subset. An unlabeled category may or may not be full, whereas the labeled categories are all full. There are, in fact, an excess of men eligible for the set of labeled categories. The men are of three types: (1) unassigned, (2) assigned to labeled categories, and (3) assigned to unlabeled categories. Types (1) and (2) are called labeled men and type (3), unlabeled men. Only unlabeled men are eligible for unlabeled categories.

It is noteworthy that the methodology of computer implementation of MAXFLOW is crucial for the efficiency of QUOTFIND. Special techniques have been developed by DSAI to maximize the speed of the labeling process. These techniques include linkage labeling, row-ordering and label preservation and have been described elsewhere.*

* See: Development of Generalized Network Flow Algorithms for Solving the Personnel Assignment Problem. Final Report, ONR contract N00014-71-C-0130. Rockville, Maryland: Decision Systems Associates, Inc. (April 1972).

3. TRANSFER

TRANSFER, a variant of the MAXFLOW algorithm, deals with the problem of adjusting imbalances in a given assignment of men to categories. As with MAXFLOW there is given a collection of categories, each with its own quota and eligibility requirements, and a collection of men, each of whom may be eligible for any of the categories. TRANSFER begins with men already assigned to categories. (It ignores those men who are unassigned.) The initial assignment is such that the categories are divided into three classes: (1) those whose quotas are not met, (2) those whose quotas are exactly met and (3) those whose quotas are exceeded. TRANSFER causes flows along chains which originate with men in overfilled categories and terminate in categories with vacancies.

TRANSFER employs a labeling procedure very similar to MAXFLOW's. The exceptions are: (1) that the labeling begins with all categories which have an excess of men instead of with the unassigned men, and (2) that subsequently no category with an excess may be labeled.

4. FQF

The method of solution underlying the sharing system requires that differential values be associated with different degrees of shortage. It is assumed that the greater the shortage, the more vital each man becomes. The closer the reduced quota is to the original quota, the less important each additional man is to the successful operation of his organization. These assumptions can be expressed by the equation:

$$\frac{dv_j}{dr_j} = k_j \frac{q_j - r_j}{r_j}$$

where: q_j = the original quota in category j

r_j = the reduced quota which is the number of men who will finally be assigned to category j

v_j = the value associated with attaining a reduced quota of r_j

k_j = a constant of proportionality called the "share-coefficient" for category j.

The equation states that the rate of change of value with change in reduced quota is directly proportional to the deficit and inversely proportional to the reduced quota.

The quota-reduction and sharing problem is to find a set of reduced quotas (r_j) which maximize the total value,

$$V = \sum_{j=1}^{JOBS} v_j$$

subject to the constraints that

(1) $\sum_{j=1}^{JOBS} r_j = N$ = the total number of assigned men

(2) $r_j \geq 0$ for all j

(3) $r_j \leq q_j$ for all j

The problem can be solved with the method of Lagrange multipliers as follows:

$$\text{Let } V^* = \sum_{j=1}^{JOBS} v_j - \lambda \left\{ \left(\sum_{j=1}^{JOBS} r_j \right) - N \right\}$$

The solution is that set of (r_j) and λ for which

$$\frac{\partial V^*}{\partial r_j} = 0 \quad \text{and} \quad \frac{\partial V^*}{\partial \lambda} = 0. \quad \text{Thus}$$

$$\frac{\partial V^*}{\partial r_j} = \frac{\partial v_j}{\partial r_j} - \lambda = k_j \frac{q_j - r_j}{r_j} - \lambda = 0$$

and $$\frac{\partial V^*}{\partial \lambda} = \sum_{j=1}^{JOBS} r_j - N = 0.$$

The equation $$k_j \frac{q_j - r_j}{r_j} = \lambda$$

implies that the solution of the quota-sharing problem occurs when the rate of change of value with respect to the reduced quota is the same for all quotas. Furthermore, the equivalent equation

$$k_j = \lambda \frac{r_j}{q_j - r_j}$$

shows how to compute the share coefficients from a given or recommended pattern of reduced quotas. Then all the share coefficients can be multiplied by an arbitrary constant, λ, without changing the solution.

For a given set of share-coefficients, however, the Lagrange multiplier, λ, is unknown and must be computed. First, it should be noted that the reduced quotas are given by the formula

$$r_j = q_j \frac{k_j}{\lambda + k_j}$$

Note that the right hand side of the formula contains the unknown multiplier λ. To solve for λ, an equation must be constructed which contains λ as the only unknown. Such an equation can be obtained by summing the r_j in the preceding formula.

$$\sum_{j=1}^{JOBS} q_j \frac{k_j}{\lambda + k_j} = N, \text{ since } \sum_{j=1}^{JOBS} r_j = N.$$

Unfortunately, there is no explicit solution of this equation for λ. Some iterative scheme such as Newton-Raphson iteration must be employed.

$$\text{Let} \quad f(\lambda) = \sum_{j=1}^{JOBS} q_j \frac{k_j}{\lambda + k_j} - N.$$

Let λ_n be the value of the n^{th} approximation to λ. Then a closer approximation to λ can be obtained by:

$$\lambda_{n+1} = \lambda_n + \Delta\lambda_n$$

$$\text{where} \quad \Delta\lambda_n = \frac{-f(\lambda_n)}{f'(\lambda_n)}$$

$$\text{Now} \quad f'(\lambda_n) = \frac{df(\lambda_n)}{d\lambda_n} = -\sum_{j=1}^{JOBS} q_j \frac{k_j}{(\lambda_n + k_j)^2}$$

$$\text{hence} \quad \lambda_{n+1} = \lambda_n + \frac{\sum_{j=1}^{JOBS} q_j \frac{k_j}{\lambda_n + k_j} - N}{\sum_{j=1}^{JOBS} q_j \frac{k_j}{(\lambda_n + k_j)^2}}$$

Of course, any iterative scheme requires an initial approximation, λ_o. To develop such an approximation, consider what happens if the reduced quotas are all large:

$$\text{Then} \quad \frac{\lambda_L}{JOBS} \sum_{j=1}^{JOBS} \frac{1}{k_j} = \frac{1}{JOBS} \sum_{j=1}^{JOBS} \frac{q_j - r_j}{r_j} \sim \frac{Q - N}{N}.$$

In other words, the mean ratio of deficit to reduced quota is approximately equal to the ratio of the total deficit to the total reduced quota.

$$\text{Hence} \quad \lambda_L \sim \frac{Q - N}{N} \qquad \frac{JOBS}{\sum_{j=1}^{JOBS} \frac{1}{k_j}}$$

On the other hand, if the reduced quotas are small:

$$\frac{1}{\lambda_S} \quad \frac{1}{JOBS} \sum_{j=1}^{JOBS} k_j = \frac{1}{JOBS} \sum_{j=1}^{JOBS} \frac{r_j}{q_j - r_j} \sim \frac{N}{Q - N}$$

$$\text{So} \qquad \lambda_S = \frac{Q - N}{N} \qquad \frac{\sum_{j=1}^{JOBS} k_j}{JOBS}$$

It is sensible to use a weighted average of λ_L and λ_S for the initial value of λ_o. The weights should depend on the size of the reduced quota. The simplest combination would be

$$\lambda_o = \frac{N}{Q} \lambda_L + \frac{Q - N}{Q} \lambda_S$$

and this is the formula which is employed in the program. Experience indicates that this initial estimate of λ_o is close enough to the root to assure convergence.

A few further observations should be made about the sharing formula. First, it should be noted that a given set of share-coefficients implies a certain set of percentages of reduced quotas to original quotas. Quotas with the same share-coefficients will have the same percentages of fill, if sufficient men are available to fill the reduced quotas. For example, if 55 men are available for fair-sharing among two quotas, 10 and 100, then the reduced quotas will be 5 and 50, even though the absolute amount of shortage is ten times as large in the second quota as it is in the first. Secondly, it should be noted that the sharing formulas prevent the reduced quotas from falling below zero or exceeding the original quotas as long as $0 \leq k_j \leq \infty$. More precisely, $r_j \to 0$ as $k_j \to 0$ and $r_j \to q_j$ as $k_j \to \infty$. Although the sharing formulas may appear complex, they are actually the simplest ones which have these properties.

Description of the OPTIMIZE algorithm

OPTIMIZE is a primal-dual algorithm based on the minimum cost flow algorithm of Ford and Fulkerson (1962). The OPTIMIZE algorithm assigns men to categories in such a way that a linear payoff function is maximized. Each assignment category has specific qualification restrictions and quota requirements, and each man may be qualified for several of these categories. The solution requires that a man is qualified for the category to which he is assigned and that the quotas of the assignment categories are not exceeded. Let:

I = number of men

J = number of categories

Q_j = quota for category j

P_{ij} = payoff if man i is assigned to category j. $P_{ij} > 0$ except if man i is unqualified for category j, in which case $P_{ij} = -\infty$.

The objective is to assign each man to one category in such a way that

(1) $\sum_{i=1}^{I} \sum_{j=1}^{J} P_{ij} \; x_{ij}$ is maximized, where

$$x_{ij} = \begin{cases} 1 \text{ if man } i \text{ is assigned to category } j \\ 0 \text{ otherwise.} \end{cases}$$

The solution is optimal only if there is a feasible solution, i.e., if there is some arrangement of assignments possible in which every man is assigned, if only to a slack quota, and all quotas are exactly met. If the feasibility condition does not hold, then an assignment solution may result in which some quotas are not filled and/or some men are left unassigned. In this case the maximality of the payoff function cannot be assured.

OPTIMIZE is divided into two main sections, DUAL and MAXFLOW. The assignment procedure consists of an alternation of processing between these sections. DUAL specifies the categories for which each man is eligible. MAXFLOW then assigns a maximum number of men under these eligibility restrictions without exceeding

quotas. Then DUAL changes the eligibilities of certain men, without destroying the eligibility of any man for the category to which he is presently assigned, and once more gives control to MAXFLOW. The procedure eventually terminates in DUAL. It is determined at that time whether the optimal assignment has been found or whether no feasible solution exists. (MAXFLOW was discussed above; the description of DUAL follows.)

In order to determine eligibilities, DUAL employs a set of "dual" variables (U_i, V_j) $(i = 1, \ldots I; j = 1, \ldots, J)$. The dual variables are unrestricted in sign. Throughout the remainder of this discussion the convention is employed that any computation which involves $\pm \infty$ yields $-\infty$ as a result.

Define the matrix of residuals by:

$$(1) \qquad r_{ij} = P_{ij} - U_i - V_j$$

The values assumed by U_i and V_j will always be such that $r_{ij} \leq 0$.

Then eligibility is defined as follows: man i is eligible for category j if $r_{ij} = 0$

Thus, if man i_o is eligible for category j_o

$$(2) \qquad U_{i_o} = P_{i_o j_o} - V_{j_o} \geq P_{i_o j} - V_j \text{ for any } j.$$

Notice that a man can never be eligible for a category for which he is not qualified, because $r_{ij} = -\infty$. After each pass through MAXFLOW, the dual variables are adjusted, but the adjustments are always made such that:

$r'_{ij} = r_{ij} = 0$ if man i is assigned to category j.

It can now be shown why an assignment under the above definition of eligibility maximizes the payoff function if the feasibility constraints are met. Suppose x_{ij} is the assignment array determined by an application of OPTIMIZE, and suppose x'_{ij} is any other assignment array. For a fixed i there is exactly one j_o such that $x_{ij_o} = 1$. For all other j, $x_{ij} = 0$.

Thus: $$\sum_j (P_{ij} - V_j)\, x_{ij} = P_{ij_o} - V_{j_o}$$

From the eligibility requirements (2) follows:

$$P_{ij_o} - V_{j_o} \geq P_{ij} - V_j \text{ for all } j.$$

Therefore:

$$\sum_j (P_{ij} - V_j)\, x_{ij} \geq \sum_j (P_{ij} - V_j)\, x'_{ij}.$$

Or, after suitable transformations:

$$\sum_i \sum_j P_{ij}\, x_{ij} \geq \sum_i \sum_j P_{ij}\, x'_{ij}$$

Thus x_{ij} maximizes the payoff function.

The procedure may begin with any finite values for the V_j. Then set:

$$U_i = \max_j (P_{ij} - V_j)$$

This has the effect of making $r_{ij} \leq 0$ and making man i eligible for at least one category, unless he is unqualified for every category, in which case the problem is a priori infeasible. Then the V_j are adjusted as follows:

$$V'_j = \max_i (P_{ij} - U_i)$$

This makes at least one man eligible for category j, unless there is no man qualified for this category. If man i_o was eligible for category j_o under V_{j_o}, then $V'_{j_o} = V_{j_o}$, and he remains eligible under V'_{j_o}
This is so because:

$$P_{i_o j_o} - U_{i_o} - V_{j_o} = 0 \text{ implies } V_{j_o} = P_{i_o j_o} - U_{i_o}$$

$$\text{and } P_{ij_o} - U_i - V_{j_o} \leq 0 \text{ implies } V_{j_o} \geq P_{ij_o} - U_i$$

$$\text{thus } V'_{j_o} = \max_i (P_{ij_o} - U_i) = P_{i_o j_o} - U_{i_o} = V_{j_o}$$

Once the initial U_i, V_j have been determined, the first pass through MAXFLOW is made.

It is easy to see that if a feasible solution exists and the V_j are chosen properly, then the optimal assignment will be achieved by the first application of MAXFLOW. In the absence of a V_j estimation method the V_j are set initially to zero.

After a pass through MAXFLOW some men have been assigned to categories, the labeling procedure is complete, and no categories with vacancies have been labeled. DUAL is designed to alter the dual variables such that the following is accomplished:

A. Every man remains eligible for the category to which he is presently assigned.

B. Every label which currently exists remains valid.

C. At least one labeled man becomes eligible for an unlabeled category.

D. $r'_{ij} \leq 0$

To achieve this, let:

$\bar{r} = \max (r_{ij})$, where
i runs over all labeled men and j runs over all unlabeled categories.

If $\bar{r} = -\omega$ or is undefined, then the procedure terminates. This may happen in the following ways:

(1) There are no labeled men and all quotas are met. In this case the assignment solution is feasible and, therefore, optimal.

(2) There are no labeled men, but some quotas are not met. Thus, all men have been assigned, but there may be some way to reassign them so as to increase the payoff.

(3) There are no unlabeled categories. Thus, all quotas are met but men remain unassigned. It may be possible to improve the payoff by switching men who are assigned for those who are unassigned, although the payoff cannot be improved by switching assigned men only.

(4) $\bar{r} = -\infty$. Thus no labeled man is eligible for any unlabeled category. In this case there are unassigned men and unfilled categories, but the qualifications of the men are such that there is no way to move them about so as to achieve a greater number assigned. It may be possible to alter the assignments so as to increase the payoff.

In the nonterminal situation $\bar{r}$ is defined and finite. $\bar{r} < 0$, because if $r_{i_o j_o} = 0$, where man i_o is labeled, then man i_o is eligible for category j_o and hence category j_o is labeled. DUAL changes the U_i and V_j as follows:

$$U_i' = \begin{cases} U_i + \bar{r} & \text{if man } i \text{ is labeled} \\ U_i & \text{if man } i \text{ is unlabeled} \end{cases}$$

$$V_j' = \begin{cases} V_j - \bar{r} & \text{if category } j \text{ is labeled} \\ V_j & \text{if category } j \text{ is unlabeled} \end{cases}$$

This adjustment satisfies conditions A, B, C and D above:

A. If man i is presently assigned to category j, then either man i and category j are both labeled or both unlabeled. In either case:

$$r_{ij}' = P_{ij} - U_i' - V_j' = P_{ij} - U_i - V_j = r_{ij} = 0,$$

so that man i remains eligible for category j.

B. A man is labeled if he is either unassigned or assigned to a labeled category. A category is labeled if there is a labeled man eligible for it. If $r_{ij} = 0$, where man i is labeled, then category j is labeled and thus $r_{ij}' = 0$. This, along with condition A, implies that all labels remain valid.

C. For labeled man i and unlabeled category j we have:

$$r_{ij}' = P_{ij} - U_i' - V_j' = P_{ij} - (U_i + \bar{r}) - V_j = r_{ij} - \bar{r}$$

Thus by definition of $\bar{r}$ there exists a labeled man i_o and an unlabeled category j_o such that $r'_{i_o j_o} = 0$, i.e., a labeled man becomes eligible for an unlabeled category.

D. This condition subdivides into three cases:

(1) Man i and category j are both labeled or both unlabeled. Then
$r'_{ij} = r_{ij} \leq 0$.

(2) Man i is labeled and category j is unlabeled. Then
$r'_{ij} = P_{ij} - (U_i + \bar{r}) - V_j = r_{ij} - \bar{r} \leq 0$ by definition of $\bar{r}$.

(3) Man i is unlabeled and category j is labeled. Then

$$r'_{ij} = P_{ij} - U_i - (V_j - \bar{r}) = r_{ij} + r < 0$$

since
$r_{ij} \leq 0$ and $\bar{r} < 0$.

Because of conditions A and B, return to MAXFLOW is possible so that the labeling process may be continued precisely where it terminated previously. Condition C insures that at least one more category will be labeled. It is this condition which guarantees eventual termination.

Description of Successive Surface Optimization Approach

The successive surface optimization methodology involves an iterative application of the OPTIMIZE algorithm designed to provide an optimal solution to a sequence of multiple, rank-ordered objective functions which are formulated in terms of binary (two-valued) payoff matrices. This methodology is extremely efficient as it retains the results of each optimization (i.e., the residual matrix at termination of each iterative sequence) to provide a reduced, feasible "surface" for each subsequent optimization.

The methodology can be applied to all assignment problems involving objectives which are expressed in terms of the categorical properties of the resources to be assigned. Such objectives can be formulated in binary terms in the sense that a specific assignment of resource i to assignment category j is either desirable or not. For each objective, this binary formulation takes the form of a hierarchical structure of two or more desirable prerequisite levels for each assignment category, with each level specifying one or more categorical properties of the resources to be assigned. The highest prerequisite level identifies the most desirably qualified resources for a specific assignment category whereas the lowest level represents the mandatory level, i.e., the least desirably qualified resources but still eligible; resources not meeting the mandatory level of an assignment category are ineligible for assignment to that assignment category.

The payoff matrix associated with each level for each objective is two-valued, containing elements $p_{ij} = 1$ if resource category i meets the level's prerequisites for assignment category j and $p_{ij} = 0$ otherwise. These payoffs can often be generated implicitly from the information stored for each row (resource) and each column (assignment category) so that there is virtually no limit to the size of the problem which can be solved. For some types of objectives, however, the payoff matrices may have to be specified externally and stored in a finite data file in central memory.

The object is to find an assignment solution with the maximum numbers of assignments at the most desirable levels for all of the objective functions involved, in order of importance of each objective. In other words, the optimization for one objective must not affect the optimal solution for a higher-ordered objective, and, in turn, once the optimal solution for this objective has been obtained, the results (i.e., the numbers assigned at each level, but not necessarily the individual assignments) constrain any subsequent optimizations. This is accomplished as follows.

For the optimization at each level, the original payoff matrix can be described as a three-valued matrix: one value for desirable (at this level), a second value for eligible but undesirable (i.e., qualified at a lower level) and a third value for ineligible (not meeting the mandatory level). In practice, these values can be represented by ones, zeroes and blanks or, alternatively, by means of two binary-valued matrices, the first indicating eligibility or not and the second indicating desirability or not.

During OPTIMIZE, these original payoff values are recomputed from the adjusted dual variables until, at the point of optimality, all of the admissible cells will contain either zero or negative residuals. Initially inadmissible cells remain, of course, inadmissible. The zero-valued residual payoffs represent optimal assignment opportunities and every row (corresponding to a particular resource) will be assigned to one of these zero-valued cells. Because the number of optimal assignment possibilities is, in general, much larger than the number of resources to be assigned, this slack may be utilized in subsequent optimizations. The negative-valued residual payoffs represent the "shadow prices" or marginal costs associated with less than optimal assignment alternatives: the values indicate the cost to the objective function if the corresponding assignments were chosen instead of the optimal ones.

The successive surface optimization technique entails, after each optimization, elimination of all cells containing negative valued payoffs (residuals) from further

consideration, i.e., conversion of these payoffs to inadmissible values. As a result, the remaining zero-valued residual payoffs define the optimal surface and, thereby, the total set of admissible cells for subsequent optimizations. Thus, this surface restricts all future optimization outcomes to those which include the current as well as prior optimal solutions as a sub-set.

After elimination of all negative valued cells, the remaining zero residual payoffs are replaced with the one/zero payoff values associated with the next objective function (or, next level for this objective function, whatever may be the case). By repeating OPTIMIZE, a new optimal solution is obtained which is constrained to the previous optimal surface. No matter how often this process is repeated, each optimization preserves the results of all previous optimizations and, in turn, constrains all subsequent optimizations.